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Page, Newman.
Paine, Cecil E.
Peck, Claude J.
Pender, Benjamin D.
Petre, Axel E.
Phillips, William H.
Piek, William F., Jr.
Pleasants, William H.
Powelson, W. Van N.

Raven, Anton A.
Raymond, James R.
Raymond, Harry H.
Rea, Samuel.
Richardson, Eugene M.
Richardson, Holden C.
Robins, William B.
Rodgers, W. L.
Rogers, Walter H.
Ross, Charles E.
Ruprecht, Fritz K.
Russel, John R.

Sabin, Alvah H.
Satterlee, Herbert L.
Schafer, Charles A.
Scholz, Robert C.
Sebree, Uriel.
Shaw, Howard L.
Shaw, William.
Simpson, Robert C.
Smith, Alfred G.
Smith, Edward.
Smith, Robert A. C.
Smith, Wm. A. F.
Speakman, Edward M.
Sprague, F. J.
Stacy, Francis N.
Sullivan, J. J.

Taylor, Stevenson Pierce.
Thomas, Joseph D.
Thompson, Robert M.
Thorp, Harry W.
Toch, Henry M.
Todt, Edward G.
Tomikawa, Naoji.
Truscott, Starr.

Van Duzer, Louis S.
Vassileff, Dimitry.
Veit, Richard C.

Wales, Charles M.
Walker, Herbert B.
Welles, Roger, Jr.
Whitaker, F. B.
White, George A.
Whiton, Chauncey G.
Wilkinson, Horace S.
Williams, Ralph D.
Williams, William E.
Winslow, John.
Wood, Henry A. W.
Wright, William L.

Young, William J. J.

JUNIORS

Allen, Walter D.

Baier, Louis A.

Colby, Haldwell S.
Colley, G. A.
Hanson, Ralph T.
Hidalgo, Angel C.

Newton, G. A.

Pulsifer, Revere B.
Roundy, Caryl H.

Schmidt, John D.

Track, Frank A.

ARTICLES OF INCORPORATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

State of New York,
City and County of New York. }

We, the subscribers, Wm. H. Webb, Chas. H. Cramp, George E. Weed, H. Taylor Gause, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, Edwin D. Morgan, George W. Quintard, Harrington Putnam and Jacob W. Miller, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name of title by which the Society shall be known in law is The Society of Naval Architects and Marine Engineers.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In Witness Whereof we have made, signed, and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

City and County of New York, *ss.:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Caps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss.:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss.:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

(Endorsed.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

Edwd. Patterson,
Justice of the Supreme Court in the State of New York in and for the City and County of New York.

CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

Article I.

Name and Object.

1. The name of this Association shall be "The Society of Naval Architects and Marine Engineers."

2. Its object shall be the promotion of the art of shipbuilding, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

Article II.

Membership.

1. The Society shall consist of Members, Associates, Juniors, Honorary Members and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A candidate of this class must be not less than twenty-five years of age and comply with the following regulations:—He shall submit to the Council a statement showing that he has been engaged in the practice of his profession, in a responsible capacity, for at least three years, and setting forth his grounds upon which he bases his claim to membership. This statement shall be signed by three members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the Members of the Council present are in favor of the admission of the candidate, his name shall be submitted to the members of the Society at the next meeting, the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of all persons who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership. If considered by three-fourths of the Council present duly qualified for Associate membership, their names shall be submitted to the Society at its next

meeting, to be voted upon by the Members and Associates, voting to be by ballot, should a ballot be demanded.

4. The proportion of votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members after fulfilling the necessary conditions; when they are twenty-six years of age they shall be offered the option of being transferred to active or associate membership, if they duly qualify; but if they do not accept such offer, or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

Article III.

Dues.

1. The entrance fees, payable on admission to the Society, shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual contributions shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving notice for the annual meeting. On election, each member shall pay his entrance fee and annual dues for the current year and be entitled to receive the proceedings of the annual meeting of the year during which he is elected.

5. Members and Associates can compound for all future dues and become Life Members and Life Associates, by making a single payment of two hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees on severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by

the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears, the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or a part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privilege of membership be enjoyed until all dues shall have been paid; if the payment be delayed for more than six months from the date of election the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be judged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be notified and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion of the case permitted; but if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (provided there be not less than twenty present) vote for expulsion, the chairman of the meeting shall cause the accused to be expelled from the Society, and direct the Secretary to notify the accused of this action.

Article IV.

Officers.

1. The officers of the Society shall consist of a President, Past Presidents, Honorary Vice-Presidents, twelve Vice-Presidents, twenty-four Members of Council, and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Vice-President, and Members of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society for the year with which the term of the President expires, the Council shall nominate a candidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing three years. The first President under this rule shall be elected at the annual meeting in 1906 and his term of office shall begin January first, 1907. The President shall not be eligible for election as his own successor.

4. The term of office of the Vice-Presidents shall be three years. The Vice-Presidents whose terms by election now expire in 1911 and 1912 shall expire as of December 31, 1911; those whose terms now expire in 1913 and 1914 shall expire December 31, 1912; those whose

terms now expire in 1915 and 1916 shall expire December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election. Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years' service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all Members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-Presidents in any one year.

5. The term of office of the Members of Council shall be three years. Prior to September 1 of each year the President shall appoint a Nominating Committee of five (Members and Associates both being eligible). This committee shall prepare a list of six Members and two Associates to fill the vacancies occurring in due course at the end of the year, and shall forward the same to the Secretary by September 1. This list of names shall be mailed as soon as practicable after September 1 of each year to Members and Associates. The ballots shall be returned by mail to the Secretary and canvassed at the annual meeting. When the said list of names has been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In case such additional nominations are made the six Members who receive the highest number of votes shall be declared elected Members of Council and the two Associates receiving the highest number of votes shall be declared elected Associate Members of Council, in each case for a term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of Member of Council shall be filled by the Council for the unexpired portion of the term of the Member or Associate causing the vacancy.

7. The Presidents, Past Presidents and Vice-Presidents shall be *ex officio* members of Council.

8. The Council may hold meetings, subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council, five members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

Article V.

Management.

1. The President shall have general supervision over affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex officio* member of all committees.

(2) In the absence of the President, the Vice-Presidents, in the order of seniority, shall preside and perform all the duties of the President.

2. The direct management of the Society shall be vested in an Executive Committee composed of five Members of Council elected annually by the Council, the President and Secretary of the Society being *ex officio* members of the Committee. At least three of the five elective members of the Committee shall be Members of the Society.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated, and the provisions of the Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers under such regulations as the Council may, from time to time, prescribe; take measures to advance the interests of the Society, and generally direct its affairs.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer and of any special committee which may have been ordered.

5. The Secretary shall be the executive officer of the Society under the immediate direction of the President and Executive Committee.

(2) He shall prepare the business for the annual meetings and record the proceedings thereof.

(3) He shall be responsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Society and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually by a special committee of three Members of the Council appointed by the President of the Society.

Article VI.

Meetings.

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings, thirty members shall constitute a quorum.

3. The Society may adopt from time to time such rules as it may think proper for the order of business at its meetings.

4. Special meetings of the Executive Committee may be held at any time subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the Committee.

Article VII.

Amendments.

1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment, it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

INTRODUCTORY PROCEEDINGS

TWENTY-FIRST GENERAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

THURSDAY MORNING, DECEMBER 11, 1913.

The Twenty-First Annual Meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York City, on Thursday and Friday, December 11 and 12, 1913.

In the absence of the President, Mr. Robert M. Thompson, the meeting was called to order by the Vice-President, Mr. Walter M. McFarland, at 10:15 o'clock.

THE CHAIRMAN:—The President of the Society, Colonel Thompson, is unfortunately absent. The Secretary has a communication from him which he will now read.

The Secretary read the following communication:

DECEMBER 5, 1913.

Fellow Members of the Naval Architects and Marine Engineers Society:

I greatly regret that I cannot be present with you at your annual meeting and banquet, but a stony-hearted doctor has sent me to Florida and denied me permission to return in time to be with you.

I sincerely regret the lost opportunity of meeting so many good fellows and men who are doing so much to advance the prosperity of the nation.

* * * * * * * * * * * * * * * * *

Your President was in London during the past summer, and, as representing you, was invited to the memorial services held in Westminster Abbey to the memory of Lord Kelvin, and our sister society, the Institution of Naval Architects of Great Britain, gave a complimentary dinner to your President. As both of these compliments were paid, not to the individual but to the representative of your Society, it is fitting that a note should be made of it and that these courtesies should be borne in mind so that they may be returned in kind if opportunity offer.

Thanking all and each of you for the honor that you conferred upon me by selecting me as your President, and regretting that I have not been able to do more to advance the interests of the Society, and with assurances that no one has the interests of the Society more at heart than has

ROBERT M. THOMPSON,
President.

THE CHAIRMAN:—The next business in order is the report of the Secretary-Treasurer.

THE SECRETARY:—The report has been distributed to all the members as usual. It will not be read in detail, but certain points will be called to your attention.

The first page relates to the membership of the Society, and on looking at that you will see that we are doing fairly well. We come to the meeting this year with 764 members. Last year we opened the meeting with 731 members. We have lost during the year by deaths and resignations a total of 34. However, with the applications for membership now on file, which have been favorably passed upon by the Council, and which will be presented to you for ratification—there are 67 which have been so approved—it will bring our total membership, with those who are elected at this meeting, up to 831. I think that is the high-water mark with regard to the membership of this Society.

As regards the finances, we make a fairly good showing. We all know that we are poor, but we cannot help that. However, we have been able to put in a trust fund the sum of $1,000 out of cash, paying all our current bills, and we have also advanced toward the Panama-Pacific Congress to be held in 1915 the sum of $500 toward a fund that the Society has guaranteed for that purpose, amounting to $2,000. This is, perhaps, a fitting time to call your further attention to that one particular matter. All of the principal scientific societies of the country have guaranteed to the Panama-Pacific Engineering Congress Committee in San Francisco, which will arrange for this congress in 1915, a total sum of $37,500. These various societies underwrote the committee to that amount, the total amount being apportioned among the societies participating, in proportion to their membership and resources, and this Society agreed to underwrite the undertaking to the extent of $2,000. That matter came to the attention of the Council prior to the last meeting, and the Council felt very strongly, in order to maintain our prestige as one of the leading societies, that it would be absolutely necessary to underwrite the share allotted to us, although it was evident from the condition of our finances that it could not be done out of the current funds of the Society. Consequently, a motion was passed by the Council, of which you were notified, that we would subscribe to the funds required by the Panama-Pacific Engineering Congress Committee—that the Society would undertake to contribute to the Congress to the extent of $2,000. The Society is, therefore, obligated to that extent to this Congress, and they are to call on us from time to time for funds as they need them. We have already had this call for $500, which we paid out of current funds, and there has been no demand made on the members as yet on this account, but you will shortly receive a notice from the Secretary in regard to this matter. It has been decided that, in order to make this matter one which the individual members shall take part in as individuals and members of the Society, that we will ask of each member a check for five dollars to be applied to this purpose; these subscriptions to remain in our treasury and to be used for the purpose of sending money to the committee for their undertaking as they may need it. The Society having obligated itself to the full amount, it is hoped when you get these notices, you will give them the attention which they deserve.

REPORT OF SECRETARY-TREASURER.

DECEMBER 10, 1913.

To the Council of The Society of Naval Architects and Marine Engineers.

GENTLEMEN:—I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1913.

The membership of the Society, November 1, 1913, was as follows:

Class of Members.	Membership November 1, 1912.	Elected at 1912 Meeting.	Promotions, Juniors to Members.	Promotions, Juniors to Associates.	Membership at close of Annual Meeting, 1912.	Deaths.	Resignations.	Membership November 1, 1913.
Members	534	40	+7	—	581	7	13	561
Associates	165	20	—	+1	186	5	6	175
Juniors	18	6	—7	—1	16	—	—	16
Life Members	7	—	—	—	7	2	—	5
Life Associates	4	—	—	—	4	—	—	4
Honorary Members	1	1	—	—	2	1	—	1
Honorary Associates	2	—	—	—	2	—	—	2
Totals	731	67	—	—	798	15	19	764

The following losses in membership occurred:

DEATHS (15).

Honorary Member (1)—

Sir William H. White.

Life Members (2)—

Charles H. Cramp. George W. Quintard.

Members (7)—

Edwin S. Alexander.
Thomas F. Carter.
Edwin S. Cramp.
William H. Fletcher.
Robert Forsyth.
Frank D. Hall.
Valdemar F. Lassoe.

Associates (5)—

Walter Ancker.
Albert W. Butler.
Henry F. Donaldson.
Anson Phelps Stokes.
Aaron Vanderbilt.

RESIGNATIONS (19).

Members (13)—

Martin A. Anderson.
J. Sellers Bancroft.
A. de Bretteville.
W. L. Cathcart.
G. R. Tuska.
Paul H. Fretz.
Axel H. Fries.
Daniel E. Hoag.
Daniel G. McAlpine.
James O. Richardson.
Robert S. Riley.
John D. Sloane.
Godfrey L. Smith.

Associates (6)—

A. T. Barnes.
F. P. Camperio.
William D. Dimock.
J. Frederic Tams.
Newton E. Mason.
Charles E. Vreeland.

The following delinquencies exist in the payment of dues:

	No.	Amount.	Total.
For the year ended December 31, 1909:—			
Associate	1		$10.00
For the year ended December 31, 1910:—			
Members	8	$80.00	
Associates	3	30.00	
			110.00
For the year ended December 31, 1911:—			
Members	25	$242.00	
Associates	10	95.00	
Juniors	7	35.00	
			372.00

For the year ended December 31, 1912:—	No.	Amount.	Total.
Members	36	$360.00	
Associates	21	205.00	
Juniors	9	45.00	
			$610.00

For the year ending December 31, 1913:—			
Members	96	$960.00	
Associates	36	360.00	
Juniors	7	35.00	
			1,355.00
Total outstanding dues, October 31, 1913			$2,457.00

RECEIPTS.

From November 1, 1912, to October 31, 1913, inclusive.

Entrance fees of new members for the year ending December 31, 1913:—		
Members and Associates	$1,232.00	
Juniors	40.00	
		$1,272.00
Dues for the year ending December 31, 1913:—		
Members and Associates	$6,270.00	
Juniors	45.00	
		6,315.00
Dues for the year ended December 31, 1912:—		
Members and Associates	$440.00	
Juniors	5.00	
		445.00
Dues for the year ended December 31, 1911:—		
Members and Associates	$225.00	
Juniors	5.00	
		230.00
Dues for the years ended December 31, 1909 and 1910:—		
Members and Associates		120.00
Membership dues in advance for the year ending December 31, 1914		65.00
Membership dues from suspensions		10.00
Sales of publications:—		
Society Transactions to members and dealers	$1,229.35	
Special editions of papers	387.24	
		1,616.59
Exchange on checks, members' dues		14.72
Banquet, Annual Meeting, 1912		1,225.00
Special fund		150.00
Interest:		
On municipal bonds, City of New York	$490.00	
On bank balances, Franklin Trust Company	29.00	
		519.00
Total receipts		$11,982.31
Balance in bank and on hand, November 1, 1912		1,808.99
		$13,791.30

STATEMENT.

DISBURSEMENTS.

From November 1, 1912, to October 31, 1913, inclusive.

Publications:		
Printing Volume 20	$5,469.27	
Miscellaneous printing	365.80	
Forwarding volumes, papers and membership year books	117.37	
Storage of volumes	98.70	
		$6,051.14
Rent of safe deposit box, Franklin Trust Co.		5.00
Expenses 20th annual banquet, November, 1912		1,263.25
Expenses 20th annual meeting, November, 1912		421.61
Exchange on remittances, members' dues		5.15
Salaries and clerical expenses		$1,380.00
Audit of books and accounts to November 1, 1912		180.00
Rent of Society Rooms		720.00
Office expenses, postage, stationery, etc.		775.45
Investment, certificate of deposit, Franklin Trust Company		1,000.00
Advanced for account of Engineering Congress		500.00
Total disbursements		$12,301.60
Balance cash, October 31, 1913:—		
In Franklin Trust Company	$1,464.40	
On hand	25.30	
		1,489.70
		$13,791.30

Statement of Resources and Liabilities.

RESOURCES.

Membership dues after deducting for deaths and resignations ($350.00) and for doubtful accounts ($350.00)		$1,757.00
Due from dealers for volumes		493.00
Accrued interest, municipal bonds		157.50
Municipal bonds, at cost		12,560.00
Certificate of deposit, Franklin Trust Company		1,000.00
Office furniture and equipment at 30 per cent reduction from cost		1,000.00
Advanced for account of Engineering Congress		500.00
Publications on hand at 50 per cent reduction from cost, excepting volumes 18, 19 and 20		4,704.35
Cash on deposit, Franklin Trust Company		1,464.40
Cash on hand		25.30
Total resources		$23,661.55

LIABILITIES.

Membership dues, paid in advance	$65.00	
Special fund	150.00	
Pamphlet paid for in advance	.50	
Total liabilities		215.50
Society's present worth, October 31, 1913		$23,446.05

The financial statements have been verified by the Universal Audit Company of New York.

Respectfully submitted,

DANIEL H. COX,
Secretary-Treasurer.

THE CHAIRMAN:—The Secretary will read the names of members, honorary, life, active and associate, whose deaths have occurred during the past year, and you will all kindly rise during the reading.

The Secretary read the list while the members were standing.

THE CHAIRMAN:—*Requiescat in pace!*

ELECTION OF OFFICERS.

THE CHAIRMAN:—At the Council meeting held yesterday afternoon certain elections were held. As you know, under the terms of the Constitution, Vice-Presidents of the society are elected by the members of the Council, and any vacancies which occur in the Council are filled by the Council.

In obedience to the Constitution, there were elected as Honorary Vice-Presidents, in the place of Messrs. Cramp and Quintard, deceased, Messrs. E. A. Stevens and F. E. Kirby.

As Vice-Presidents for the term ending December 31, 1916, there were elected Messrs. J. W. Miller, R. M. Watt, A. P. Niblack and W. M. McFarland.

As Vice-Presidents to fill the vacancies caused by the promotion of Messrs. E. A. Stevens and F. E. Kirby there were elected Messrs. W. I. Babcock and W. F. Durand; and to fill the vacancy in Council caused by the promotion of Mr. W. I. Babcock, Mr. J. H. Linnard was elected a Member of Council.

As Secretary-Treasurer, Mr. Daniel H. Cox was re-elected.

As the Executive Committee for the ensuing year, the following named gentlemen were elected:—Messrs. W. L. Capps, Lewis Nixon, W. I. Babcock, Stevenson Taylor and David W. Taylor.

The Society itself, by ballot, has chosen for the term ending December 31, 1916, the following Members of Council:—Messrs. W. I. Babcock, W. L. R. Emmet, A. L. Hopkins, C. W. Jungen, C. A. McAllister and H. P. Norton.

As Associate Members of Council, for the term expiring December 31, 1916, the Society has elected Messrs. R. A. C. Smith and J. R. Andrews.

At the meeting of the Council yesterday, the applications for membership were received and duly examined, and the Secretary will now read to you a list of those who have been certified to the society by the Council as recommended for election to the grade of Membership, to the grade of Associate, and to the grade of Junior, respectively.

Election of New Members.

The Secretary read the following list:—

Members (28).

R. E. Anderson, Assistant to General Manager, Lake Torpedo Boat Co., Bridgeport, Conn.

George Allen Anthony, Marine Engineer, War Department, Washington, D. C.

Luigi Barberis, Naval Constructor, Italian Navy, Ministero Marina, Roma, Italy.

Harry W. Broady, Chief Engineer, Welin Marine Equipment Co., 305 Vernon Avenue, Long Island City.

Geheimer Oberaurat Buerkner, Chief Constructor, German Navy, Reichs Marine Amt., Berlin.

Myron Blodgett, 312 Lyceum Building, Duluth, Minn., Superintendent of Repairs for O. W. Blodgett.

Norman A. Currier, Steamboat Inspector, Halifax, Nova Scotia.

John W. Graham, Superintendent Engineer, A. H. Bull Steamship Co., 1570 73d Street, Brooklyn, N. Y.

Nelson W. Howard, Superintendent, Geo. Hall Coal Co., Ogdensburg, N. Y.

David J. Irish, Mechanical Engineer, Babcock & Wilcox Co., Bayonne, N. J.

Thomas W. Jackman, Engineer, Mutual Transit Co., P. O. Box 987, Buffalo, N. Y.

Arthur H. Jansson, Engineering Department, Welin Marine Equipment Co., 305 Vernon Avenue, Long Island City.

Frederick W. Jones, Chief Engineer, Mechanical Dept., N. Y., N. H. & H. R. R. Co., Harlem River Station, New York, N. Y.

Robert MacNab, Assistant Naval Constructor, Marine and Fisheries Department, Ottawa, Canada.

Anderson MacPhee, Marine Engineer, Schutte & Koerting Co., Philadelphia, Pa.

John E. Otterson, Assistant Naval Constructor, U. S. Navy, Navy Yard, Boston, Mass.

Richard Pemberton, Government Overseer, Department of Marine and Fisheries, Ottawa, Canada.

Edward A. Plunkett, Agent, Jas. Shewan & Sons, Ft. 27th Street, Brooklyn, N. Y.

Arthur Morris, Naval Architect, Elswick Shipyard, Newcastle-upon-Tyne, England.

John Shields, President, Atlantic Basin Iron Works, 27 Imlay Street, Brooklyn, N. Y.

John Sharp, Chief Engineer, Polson Iron Works, Toronto, Canada.

Edwin B. Sadtler, Agent in New York, New York Shipbuilding Co., 50 Church St., New York, N. Y.

Augustus Suzara, Chief Engineer, Bureau Navigation, Manila, P. I.

Karl H. Schaffran, Chief Engineer, Royal Prussian Experimental Tank, Berlin, N. W., Kirchstrasse 25.

Wassily W. Wassilieff, Foreman, Sveaborgsky, Port Helsingfors, Russia.

J. Murray Watts, Naval Architect, 326 Chestnut St., Philadelphia, Pa.

Frederick A. Willsher, Chief Draughtsman, Geo. T. Davis & Sons, Levis, Quebec, Canada.

Henry T. Wright, Naval Constructor, U. S. Navy, Navy Yard, Norfolk, Va.

Associates (32).

George D. Ali, Manager, Foreign Shipping Department, Standard Oil Co., 26 Broadway, New York, N. Y.

William H. Becker, Treasurer, Pollock-Becker Co., P. O. Box 987, Cleveland, Ohio.

Alva Bradley, Secretary-Treasurer, Alva Steamship Company, 706 Marion Building, Cleveland, Ohio.

Omer W. Blodgett, Vessel Owner, 312 Lyceum Building, Duluth, Minn.

Harry S. Bradley, Asst. General Mgr. Wheeling Mold & Foundry Co., Wheeling, W. Va.

Harvey H. Brown, 1624 Rockefeller Building, Cleveland, Ohio.

Richard B. Cook, Draughtsman, Cox & Stevens, 15 William Street, New York, N. Y.

Thomas C. Burke, Attorney-at-Law, 1035 Marine National Bank Building, Buffalo, N. Y.

Harry Coulby, President, Pittsburgh Steamship Co., Rockefeller Building, Cleveland, Ohio.

Harry S. Demarest, Sales Manager, Greene, Tweed & Co., 109 Duane Street, New York, N. Y.

Edwin T. Douglass, General Manager, The Western Transit Co., 48 Main Street, Buffalo, N. Y.

Edward H. Ellison, Chief Engineer, Art Metal Construction Co., Jamestown, N. Y.

Charles W. Elphicke, Vessel Owner, Western Union Building, Chicago, Ill.

Otto L. Halenbeck, Assistant Manager, Lighterage Department, Standard Oil Co., 26 Broadway, New York, N. Y.

William A. Hawgood, Marine Engineer, Perry-Payne Building, Cleveland, Ohio.

W. R. Haynie, U. S. Representative, Charles Freres, Ghent, 30 Church Street, New York, N. Y.

Charles M. Heald, President, Mutual Transit Co., 1318 Chamber of Commerce, Buffalo, N. Y.

Lawrence L. Henderson, General Manager, Montreal Transportation Co., Montreal, Canada.

Sherwin A. Hill, Attorney-at-Law, 905 Union Trust Building, Detroit, Mich.

Carl C. Joys, President, Vance & Joys Co., 211 Mitchell Building, Milwaukee, Wis.

James H. B. MacKenzie, Consulting Engineer, 24 Stone Street, New York, N. Y.

S. Victor McLeod, Superintendent, Algoma Central Steamship Co., Sault Ste. Marie, Ontario, Canada.

Frederick A. Meyer, Secretary, Smith, Davis & Co., Buffalo, N. Y.

James S. Morton, President, The Gretham & Morton Transportation Co., Benton Harbor, Mich.

Claude J. Peck, Manager, The Shenango Steamship Co., Cleveland, Ohio.

Fritz K. Ruprecht, Draughtsman, Robins Dry Dock Co., 1 South Oxford Street, Brooklyn, N. Y.

John L. Russel, Vice-President and Treasurer, Great Lakes Engineering Works, Detroit, Mich.

Howard L. Shaw, General Manager, The Lake Transit Co., Bay City, Mich.

Edward Smith, President Buffalo Dry Dock Co., 1116 New Marine Bank Building, Buffalo, N. Y.

Francis N. Stacy, Statistician, Lake Superior & Mississippi Canal Commission, Holland House, New York, N. Y.

J. J. Sullivan, Bank President, Cleveland, Ohio.

Horace S. Wilkinson, President, Toledo Shipbuilding Co., Toledo, Ohio.

Junior (1).

Caryl H. Roundy, Draughtsman, Hull Division, Navy Yard, Norfolk, Va.

Associate to Member (2).

Walter A. Clarke, Fore River Shipbuilding Co., Quincy, Mass.

A. W. Frank, Assistant Naval Constructor, Navy Yard, New York, N. Y.

Junior to Member (2).

Gordon G. Holbrook, Estimator, Engineering Department, Bath Iron Works, Bath, Me.

F. A. Cook, Atlantic, Gulf & Pacific Co., New York, N. Y.

THE CHAIRMAN:—Gentlemen, you have heard the recommendations of the Council. What is your pleasure?

On motion, duly seconded, the recommendation of the Council that the applicants be elected to the various grades for which they had applied was approved.

THE CHAIRMAN:—The gentlemen are declared to be elected to the various grades of membership indicated in the report of the Secretary.

Vice-President McFarland then read the following address:—

ADDRESS OF THE PRESIDING OFFICER.

The Society of Naval Architects and Marine Engineers.

GENTLEMEN:—At the last meeting of the Society, a portion of the President's address was devoted to a notice of the death of some of our distinguished members. That sad duty arises again this year, as we have lost two of our Honorary Vice-Presidents, Mr. Charles H. Cramp and Mr. George W. Quintard, and our oldest Honorary Member, Sir William H. White, K. C. B.

In their day of activity, Messrs. Cramp and Quintard were leaders in our profession, both being at the head of establishments famous in marine work. I count it a privilege to have known both of these distinguished men and to have been honored with their friendship, and I am glad to have the honor of bearing testimony to their ability and to their splendid work for American shipbuilding. They were among the founders and incorporators of our society, and were vice-presidents from the beginning. They showed their interest by becoming life members and thereby helping to give the Society a solid financial basis.

As Mr. Quintard's funeral occurred in New York, the Society was represented among the honorary pall-bearers, and a great many members were present at the service. In the case of Mr. Cramp and of Sir William White, this was not possible, and resolutions of condolence were sent to their families.

Sir William White has been an honorary member of the Society since November, 1904. He was one of the world's greatest naval architects, and no man was more revered by his brethren on this side of the ocean.

The report of the Secretary-Treasurer at the last meeting showed a total membership of 731 and during that meeting 67 new members were added, so that at the close of our 1912 meeting we had a membership of 798. During the past year the Society has suffered somewhat by deaths and resignations, but these losses have been more than offset by the new membership just elected.

It is also a noteworthy fact that a great improvement is shown in the payment of back dues and that it was not necessary to drop any members after the meeting last year for failure to pay their dues. All those in substantial arrearage either paid up or showed an inclination to make partial payments.

The financial condition of the Society demonstrates careful management of our limited resources. We find that our Secretary-Treasurer has been able, after paying all current bills, to forward $500 to the committee in charge of the Panama-Pacific Engineering Congress, to invest in a certificate of deposit for $1,000, and that a substantial balance remains on deposit.

It will be noticed that the Society is holding its annual meeting nearly a month later than usual. This change was decided upon by the Council in order to accommodate the active and energetic membership which comes from the Great Lakes, and who, owing to conditions existing about the middle of November, have never heretofore been able to attend our meeting in the numbers desired. We must say that our Lake friends have made a strong and

persistent effort to arouse interest in this change, and as a consequence we have a large number of new members.

As a consequence of the terrible Titanic disaster, an international conference has been held in London of the world's foremost naval architects, in order to bring about a world-wide effort to minimize, as far as mortal man is able, the dangers of vessels at sea.

I am proud to say that the membership of this Society has taken a distinguished part in that conference, the delegates who were members being Admiral W. L. Capps, Commissioner E. T. Chamberlain, General George Uhler, Mr. H. L. Ferguson and Mr. A. G. Smith.

Furthermore, the proceedings of this Society have been drawn upon for consideration of this question, and a large number of papers were despatched some time ago to the Board of Trade for use in its consideration of the subject.

It was decided at the last meeting that this Society should participate in the International Congress to be held at the time of the Panama-Pacific Exposition in 1915, and I wish to commend this matter to your attention. You have received circulars in regard to the matter, and as this Congress will be a notable one you would do well to take part.

You have also received circulars in regard to the memorial to be erected to Sir William White, in London. It is certain that no man ranked higher than he in the profession of naval architecture and marine engineering. One of his most valued awards of merit was his honorary membership in this society, and I am sure that those of you who were so fortunate as to meet him never met a more perfect gentleman. We could in no more fitting way show our great admiration for Sir William White and our sincere regret at his death than by making a substantial response to the invitation of the British society to join in securing an appropriate memorial to his memory.

Turning now to some matters of technical interest during the past year, we may note that, as might have been anticipated, the loss of the Titanic has had a considerable effect. The sister ship, Olympic, was withdrawn from service for a number of months while an inner skin was fitted. It was, I think, the general opinion that, if the Titanic had had such a double hull, she would not have been lost.

The circumstances attending the Titanic disaster (where, owing to the ice-fields, the water was quite smooth, and probably all of the people on board could have been saved if there had been enough boats) led to a general demand that sea-going ships should be fitted with ample provision of lifeboats for everybody on board. This in its turn has caused marked attention to be given to improved forms of cranes, to insure the rapid and safe lowering of the boats.

This audience, well posted on such matters, needs only to be reminded that the circumstances of the Titanic's loss were very unusual, and that the calm sea which prevailed on that occasion could not ordinarily be expected. In consequence, designers and seafaring men generally have been of the opinion that it is more important to make the ship herself as nearly as possible reliable and unsinkable, rather than to place dependence on the boats. This view of the problem had a striking confirmation recently in the loss of the steamer Volturno by fire. It will be remembered that through the beneficent agency of wireless telegraphy the doomed vessel was, in a comparatively short time, surrounded by a fleet of other vessels, all anxious to render assistance; but the sea was so rough that it was practically impossible for boats, even manned by expert seamen, to do any effective work. The opportune arrival of an oil tank steamer, and the subsequent reduction of the force of the sea by the application of oil enabled the boats to be employed.

We note, also, that in cargo vessels, improved methods of construction intended to give maximum strength and capacity with minimum of material are being employed.

With respect to machinery, it may be remarked that the increased use of the Diesel engine has not been so rapid as its enthusiastic admirers anticipated. It was, of course, obvious to all naval architects and marine engineers that the general use of the Diesel engine depends on the ability to construct single cylinders of large power. Although we still hear of experiments with cylinders of 1,000 and of 2,000 horse-power, and even rumors of vessels that are to have engines with such cylinders, I think I am correct in saying that up to date the largest cylinders which have been used in successful installations are of about 300 horse-power. As a consequence of this, an equipment of several thousand horse-power means a multiplicity of cylinders, with all the numerous parts requiring care and attention.

In this progressive age it would be exceedingly unwise to say that any problem in mechanics (which does not absolutely defy natural law) is impossible, but all who have studied the problem of the Diesel engine will realize that the construction of cylinders for large powers is an exceedingly difficult one. If a metal could be discovered with all the good qualities of cast iron and about four or five times its thermal conductivity, the problem would be much simplified.

There is another aspect of the Diesel engine which is not often referred to; namely, that not all kinds of fuel oil are adapted to its use. This is not surprising when it is remembered that some of the oils have a large percentage of silt and other impurities, and it would hardly need to be mentioned but for the fact that, in the early days, it was claimed that any kind of fuel, including powdered coal, was entirely suitable.

The most serious commercial drawback to the Diesel engine has been the recent increased price of oil. When crude oil could be obtained for two cents a gallon or thereabouts, there was no question of the fuel economy as measured in dollars. Speaking roughly, the Diesel engine has about double the efficiency of the steam engine; and also speaking roughly, when burned under a steam boiler, average coal and average oil are of the same thermal value, as measured in money, when the price of the coal per ton in dollars is twice the price of the oil per gallon in cents; or, in other words, two-cent oil is equal to four-dollar coal. It thus appears that when the relative engine efficiencies are taken into account, the Diesel engine with two-cent oil would be equal to the steam engine and boiler with coal at two dollars a ton. When the price of oil is doubled, however, this advantage is lost; and from the figures given it is easy to see that, speaking roughly, when the price of oil is above four cents a gallon, a good steam-engine and boiler will produce power at a less money cost for fuel per unit than the Diesel engine.

I may remind you that our Vice-President, Admiral Cone, while Engineer-in-Chief of the Navy, arranged for the building of a Diesel engine for one of the navy fuel ships, and this work is now under way at the New York Navy Yard. When this engine is finished, the Navy Department will undoubtedly conduct extended experiments which will give a great deal of valuable information.

The limitation as to the quality of oil mentioned above does not seem to hold where it is a question of using oil as fuel under steam boilers. Well-designed burners give good results even with Mexican oil and all its impurities.

The many advantages of oil fuel, where its price is not prohibitive, commend it very highly, and its use on steam vessels is steadily increasing.

For naval vessels, water-tube boilers have for many years been used exclusively. In the merchant marine their introduction is not as rapid as their merits would seem to warrant, although they are being used more and more widely for service in all parts of the world. My study of this subject has led me to attribute the rather gradual adoption of these boilers in the merchant service to conservatism, the existing plants for the manufacture of cylindrical boilers, and their cost. My personal relations to this subject suggest that I should not, in an address of this kind, go into the matter more fully, although I have felt that the subject ought to be mentioned.

As in the case of the water-tube boiler, so in that of steam turbines, their use has now become practically exclusive in naval vessels. It has been realized almost from the first that the faster the vessel the better the opportunity for the turbine, and the recent very high-speed destroyers have shown this conclusively. For slower vessels there are now three methods of adapting the turbine so as to secure high steam economy in the turbine and also high propeller efficiency, all of which are essentially forms of reduction gear, although the details are quite different.

The simplest form is undoubtedly the mechanical reduction gear which was first proposed by Admiral Melville and has been developed in this country by Mr. George Westinghouse. In a form differing as to some details, it has been very successfully applied in England by Sir Charles Parsons. The figures, as I last heard them, were that more than 380,000 horse-power of geared turbines has been installed there. Two vessels have 30,000 horse-power each. As a matter of sentiment, I am sure you will all be pleased to know that on the naval repair ship Melville, named after our late associate, Admiral Melville, his gearing is to be used.

A second form of reduction gear is the electric drive, on which a paper describing its installation on the U. S. naval collier Jupiter is to be read at this meeting. A cargo boat for the great lakes, designed by one of our members, where Diesel engines are the motive power, also utilizes the electric drive. I believe a third example of this system is now under construction in England.

The last method is the hydraulic reduction gear, of which one example is now under construction in Germany.

For motor boats, nothing has thus far been found to surpass the gasoline engine. The enormous use of automobiles and motor boats of all kinds has given an unequalled opportunity for the perfection of this form of engine. From the thermal viewpoint I imagine little improvement is to be expected, but from time to time certain mechanical improvements are made, some of which are of very great value.

Much has been written about the possibility of the straight gas engine, operating in connection with a gas producer. So far as I know, only a few installations of this kind have been made, and those only on a small scale. From what I know of gas-engine practice on land, it would seem to me that this problem for large powers would have many of the same difficulties as obtain in the case of the Diesel engine. Here, too, it would be absurd to say that large engines of this type may not be produced that will give great satisfaction, but the outlook at present does not seem promising.

It must always be a source of keen chagrin to the occupant of this chair, as it is to me, to be unable to tell you that there is a big increase in the number of vessels in our shipyards for the foreign trade. A few vessels are now under construction for trading to the west coast of South America, but with this exception our yards are doing absolutely nothing along this

line. I have urged in the past that our Society should take active steps to secure action from Congress looking to some encouragement of our shipbuilders in this regard, but thus far we have done nothing.

It looked at one time as though a scheme, championed by one of our prominent members, was going to receive a trial by virtue of the provision of the new tariff law which allows a reduction of duty on goods imported in American ships. It appears, however, that the diplomats of other countries were more clever than our own in the drafting of commercial treaties, and that our hands are tied unless our government denounces nearly all such treaties. This is, of course, a very serious matter, and one requiring careful thought before action is taken. It does seem, however, as though statesmanship could not find a better field than action which would build up a great industry and give employment to a large number of our citizens.

I have just learned from one of our members who has given this subject very careful study that the foregoing statement is rather too inclusive. It appears that the status of the treaty question is such that the law can be enforced to a limited extent, as not all countries have treaties to prevent it. The benefit which would come from even this partial application of the law would be very helpful to the creation of an American built commercial fleet in the foreign trade.

Years ago, when our principal exports were the product of the farm and the plantation, and when, indeed, the proportion exported was equal to, or greater than that consumed at home, there might have been ground for the old theory that each country should confine itself to what it could produce cheapest; but circumstances have changed and we are now facing the question of possibly importing food stuffs ourselves.

It now costs more to build and to operate vessels flying the American flag than those of other countries, for well-known reasons, among them the high scale of all American wages. But it certainly does not follow that this will always be true. If we had never assisted promising industries because their unaided product would cost more than it could be bought for abroad, we should not now lead the world, as we do, in the manufacture of steel and other products. We believe that, with reasonable encouragement from the government, a large fleet in the foreign trade will be built up, carrying our own flag, and that the general benefit to the country will be so great as to make the aid seem entirely insignificant. We believe that enlightened statesmanship might profitably be employed in this great constructive work, and we feel, therefore, that we are not demanding anything unreasonable when we ask that American shipping should receive the fostering care of the government.

The Chairman:—We now come to the main purpose of the meeting, the reading and discussion of the technical papers, and the first one on the program I am sure will give you great pleasure, as it comes from a man of great reputation, Naval Constructor D. W. Taylor, U. S. N., who is a vice-president of the Society. His paper is entitled "Relative Resistances of Some Models with Block Coefficient Constant and other Coefficients Varied."

Naval Constructor D. W. Taylor, *Vice-President:*—Mr. President and gentlemen, this is a very short paper, and it is practically contained in the abstract. In order to save time, as all of the members have the paper, I will simply read the abstract.

RELATIVE RESISTANCES OF SOME MODELS WITH BLOCK COEFFICIENT CONSTANT AND OTHER COEFFICIENTS VARIED.

By Naval Constructor D. W. Taylor, U. S. N., Vice-President.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

Five years ago I had the honor to read before the Society a paper dealing with an experimental investigation into the influence of midship-section shape upon the resistance of vessels. That paper, as was carefully pointed out in it, dealt with shape and not with area, the sectional area curves for the various shapes being identical. Moreover, it dealt with deep water conditions only.

In this paper I propose to give the results of some investigations where both shape and area vary, and where experiments were made in very shallow as well as deep water.

When in designing a new vessel we have fixed on dimensions and displacement, the block coefficient is fixed. But with a given block coefficient we may adopt a fine midship section coefficient with resulting full ends, or a full midship section coefficient with resulting fine ends.

In the experiments I am dealing with there were 20 models tested. There were 4 groups of 5 each, the block coefficients of the group being .56, .60, .64 and .68. The midship section coefficients used with each block coefficient were .86, .92, .98, 1.04 and 1.10. All models were 20 feet long, of 2,500 pounds displacement in fresh water, and 40 cubic feet immersed volume.

Table I below gives the dimensions and coefficients for the 20 models. The ratio of breadth to draught was 2.4 in every case, and, of course, with variations of block coefficient there were corresponding slight changes in actual breadth and draught as indicated in Table I.

Table I.

Dimensions and coefficients of model 20 feet long and 40 cubic feet submerged volume, or 2,500 pounds displacement in fresh water.

Block coefficient. b	Breadth. B	Draught. H	Midship section coefficient "m."				
			.86	.92	.98	1.04	1.10
			Longitudinal coefficients.				
.56	2.928	1.220	.6511	.6088	.5714	.5384	.5091
.60	2.828	1.179	.6977	.6522	.6123	.5769	.5455
.64	2.739	1.141	.7441	.6956	.6530	.6153	.5818
.68	2.657	1.107	.7907	.7392	.6939	.6538	.6182

Plate 1 gives the body plans of the 5 models of .60 block and having midship section coefficients varying from .86 to 1.10, the midship section coefficient being indicated below each body plan. The lines are not, perhaps, the best to be obtained for speed. Conventional lines were aimed at, although, of course, the higher midship section coefficients are materially greater than used in practice.

Plate 2 shows the water lines and sectional area curves for the 20 models. The body plans for the .60 block models as shown in Plate 1 may be regarded as the parent lines for the 15 models of the other block coefficients. The process of transition is simple. Starting with the .60 block model, imagine it expanded or contracted transversely until the midship section area is that for the new block coefficient. This expanded or contracted model will not have the curve of sectional area desired, but by shifting sections forward or aft as required the form with the desired curve of sectional area is readily obtained.

It will be observed in Plate 2 that the curves of sectional area have a small ordinate at the forward perpendicular. In actually making the models the corners shown are rounded off on the model, the amount removed, however, being infinitesimal.

Plate 3 shows contours of wetted surface coefficient plotted over the range of midship section coefficient and block coefficient of the 20 models. The wetted surface coefficient is the well-known coefficient C in the formula

$$\text{Wetted surface} = C\sqrt{DL}$$

where D is displacement in tons in salt water, and L is water line length in feet.

The variation of C in Plate 3 is as might be expected from what we already know of the effect of variation of form upon wetted surface. If we keep m constant and vary the block coefficient, b, there is very little change in the wetted surface; it decreases from $b = .55$ to about $b = .65$, but from .65 to .70 remains practically constant. If we keep the block coefficient constant and vary the midship section coefficient there is appreciable variation of wetted surface for all blocks, the maximum for a range from an m value from .86 to 1.10 being about 6 per cent. The fact that the wetted surface coefficient diminishes from about 16.3 when m equals 1.10, to about 15.3 when m is equal to .85, or thereabouts, should not lead us to conclude that a smaller value of m will involve further material diminution in the wetted surface coefficient. As a matter of fact, 15.3 is very close to the minimum wetted surface coefficient obtainable, and if we continued to decrease m we would find the wetted surface beginning to rise again.

The 20 models were run in the usual way in the full depth of the model basin —14 feet in the center—and were afterwards tested, with a false bottom in place, in water 20 inches deep. The results are given in Plates 4 to 12.

Plates 4, 5, 6 and 7 give results as curves of effective horse-power in deep water for 500-foot ships displacing 17,850 tons upon the lines of the models. One figure is given for each block coefficient, the 5 curves in each figure referring to the 5 models of varying midship section coefficient.

It will be observed that except for very low speeds, where the smaller wetted surface associated with the fine midship sections has predominating influence upon resistance, the least effective horse-powers are found associated with the large midship section coefficients. In fact, for the vessels of large block coefficient less power would be required with midship section coefficients greater than unity. I think, however, we may safely say that the small powers found associated with the large midship section coefficients are not due entirely to the large coefficients. The larger midship section areas resulting from the larger coefficients enable us to obtain finer ended vessels, or vessels of finer longitudinal coefficient, and this more advantageous longitudinal distribution of displacement for the speeds at which tested helps to reduce the power.

I come now to shallow water results. The depth of water over the false bottom was 20 inches while the draughts of the models, as shown in Table I, varied from a little over 13 inches to about 15 inches, leaving comparatively small clearance under their keels.

It was found impossible to obtain consistent results for these models if they were run at speeds appreciably above three knots. At such speeds unstable eddies caused resistance for a given speed to vary radically. Accordingly these models were tested up to three knots only, and even then the results were materially more erratic than in deep water and required some cross-fairing of the experimental spots to make them consistent.

In Plates 8, 9, 10 and 11 will be found shallow water results expressed as curves of effective horse-power for vessels 300 feet long, of 3,857 tons displacement, and in water 25 feet deep. Examination of these curves discloses the fact that in this shallow water the large midship section coefficients are at a disadvantage. Except for the highest block coefficient the curves of effective horse-power arrange themselves in order with the smallest midship section coefficient at the bottom.

There is another material departure from the deep water results. In deep water, broadly speaking, the finer the block coefficient the less the effective horse-power, but in the shallow water the effective horse-power at ten knots, for instance, is very materially greater for the vessels having a block coefficient of .56 than for those having a block coefficient of .64.

The differences between deep and shallow water are perhaps more clearly brought out by Plate 12, which shows curves of residuary resistance in pounds per ton plotted on

$$\frac{V}{\sqrt{L}}.$$

Needless to say that the higher curves for each block coefficient are for shallow water. The difference is quite remarkable.

I should like to explain the shallow water results, but this is almost the first systematic investigation which we have been able to make of shallow water resistance and I do not feel that the data so far obtained are sufficient to enable any final conclusions to be drawn.

It is obvious that the full-ended models run materially better in this shallow water than the fine-ended models. We know that for very high speed in deep water the same thing occurs, namely, that full-ended models are superior to fine-ended models. This is the case, for instance, at speed-length ratios of 1.5 and over. It may be that in the shallow water the same type of form drives easiest at low speeds.

Another possible explanation is that in shallow water the shape of the midship section has the most material influence upon the resistance and that the low resistances associated with the fine midship sections are due mainly to these fine sections and not to the accompanying full ends. If this is the case the coefficient of midship section has a different effect upon resistance in shallow water from that which it has in deep water. My 1908 paper showed clearly that for the speeds we are now considering in deep water the full midship section coefficients were favorable to speed.

If I must venture one conclusion, which seems warranted by the shallow water experiments, it would be that, unless for excessively shallow water, there is probably no gain as regards resistance by adopting a midship section coefficient materially below .90.

It will be observed that even for the very shallow water in which these models were tested there was very little gain in dropping from midship section coefficient of .92 to one of .86. I would anticipate that as the water deepens the larger midship section coefficients would show a steady gain, and that for any depth of water greater than, say, 1¾ times the draught there would be no advantage from the point of view of resistance in adopting midship section coefficients below .90.

Pending systematic investigation of the features of form associated with minimum resistance in various depths of water it would seem that there are possibilities of great gain by careful model basin investigations of vessels of importance intended for shallow water work.

DISCUSSION.

The Chairman:—Gentlemen, this paper is before you for discussion. Mr. Taylor's work is invaluable, and has an international reputation, and the least tribute we can pay to it is to give it a thorough discussion. Professor Peabody, are you prepared to say anything?

Prof. C. H. Peabody, *Member of Council:*—The statement in the introduction made by our chairman is, after all, the most important thing we can say in regard to the papers presented by our honored member. The several papers which he has presented to this Society and other publications which he has offered present a body of information which is

larger and more important than that presented by any other investigators except William Froude and his son.

I do not feel that any discussion which can be given here from the floor will add to the importance of the work which is presented, and I am sure that we shall receive it in the same way we have other work as presented from time to time, and shall give it the greatest appreciation, namely, that we shall continue to use it for a long time to come.

Prof. H. C. Sadler, *Member of Council:*—I regret that as I only returned from London last night I have not had time to really examine Mr. Taylor's paper very carefully, but I have had occasion to do some work in shallow water, and I may say that the results I have obtained confirm those of Mr. Taylor. When we get to very shallow-water work, the flow around the model is, of course, approaching that of two dimensional flow, instead of three, and it always seemed to me that that is the possible explanation why we sometimes find the finer vessels harder to drive in shallow water than the fuller ones. In the models shown by Mr. Taylor the fine vessel is broader and deeper than the full vessel. If the flows take place as he mentions, the wider and deeper vessel, even though of a finer form, might possibly have the larger stream-line resistance.

In testing some barges a year and a half ago, I found some confirmation of that. A barge of fine form, when loaded to the same displacement as one of a fuller form, drove harder, and it seemed to me that the explanation was that the full vessel had more water between her bottom and the false bottom than the finer one, and there seems to be less opportunity for the water to flow in three dimensions in the latter case. Perhaps that is some confirmation of the results obtained by Mr. Taylor.

I am sure we are all deeply indebted to him for this additional information, and on reading the paper more carefully, if any other point occurs to me, I will communicate it in writing later.

Mr. Stevenson Taylor, *Past President:*—Only those who have made similar experiments to those described can properly discuss this paper.

The charts show clearly the results obtained by Constructor Taylor and they are very interesting. They are especially so to me because I have particularly followed the building of one class of steamers—those for Long Island Sound service—for many years.

One of the models, sixty per cent block coefficient and ninety-eight per cent midship coefficient, corresponds very closely to the model of the old Fall River Line steamers Bristol and Providence, constructed of wood in 1866 by the late William H. Webb. These steamers represented in style and construction the greatest advance at one step made before their time. The dead rise at midship section of these steamers was only three inches in a half-breadth of twenty-four feet. Their lines have been closely followed in the construction of similar steamers built since their time. The model to which I have referred shows on the chart most satisfactorily for both deep and shallow water. Only those with a greater midship coefficient—something not thought of while vessels were mostly constructed of wood—exceed it in efficiency.

On behalf of the Society I thank Mr. Taylor for his exceedingly interesting paper, which shows so graphically the important results of his experiments.

Naval Constructor Joseph H. Linnard, *Member of Council:*—I have been very much interested in this paper, and what I wish to say is more in the nature of an inquiry than

anything else. I notice that in Mr. Taylor's experiments only one shallow draught was used. I dare say that time and pressure of work in the basin, or other circumstances, were such as to prevent a series of experiments at different draughts.

I think it might be interesting if Mr. Taylor would state something of the nature of the false bottom used, and whether it was considered that additional information of an important character would be derived from a series of experiments at different draughts.

THE CHAIRMAN:—Does any other member wish to contribute to the discussion?

PROF. HAROLD A. EVERETT, *Member:*—I ask Mr. Taylor if, in his judgment, the results would be affected if block coefficients greater than .68 were taken, perhaps .78?

THE CHAIRMAN:—If no other member wishes to discuss the paper, we will ask Mr. Taylor to close the discussion.

NAVAL CONSTRUCTOR TAYLOR:—I will try to reply briefly to the questions raised. I should like, first, to express my appreciation of the very kind remarks made by the gentlemen who discussed the paper.

As regards Professor Sadler's statements, I was pleased to find that his results have confirmed those we found, because he has done a great deal of this work—this shallow water work—and we have done very little, and, as I stated in the paper, the results were rather unexpected. So I am glad that we are in agreement on that point, at any rate. I am very glad he was able to throw some light on the probable cause of these unexpected results. I did not venture to assign a cause myself, for the simple reason that I did not know what it was. We have found in most of our model work before this, and it is confirmed by these experiments, that, strange as it may seem, the very full midship section is advantageous from the point of view of resistance. I am glad such an authority as Mr. Stevenson Taylor agrees with that as regards results from actual practice. Many people who build vessels are not willing to go as far in that direction as is indicated to be desirable from the results of model basin experiments.

As regards Professor Everett's question, if you examine the diagram you will see that the reduction of resistance has apparently reached its limit at a block of .64. For the blocks .68 there is a very slight increase, and I should anticipate that if we had carried these experiments in this particular case to a block of .78, deriving the .78 block in the same manner, there would have been a very appreciable increase, probably a material increase, over the .68. The minimum probably occurs somewhere between .64 and .68.

With reference to Mr. Linnard's question about the false bottom, it is a fact that time would not admit of the experiments being made at more than one draught, in fact we were barely able to finish the shallow-water experiments in time to have the paper in the hands of the printer in time for publication. The false bottom used was the bottom made originally for some experiments for the New York Harbor Line Board. They wished to have some experiments made on the disturbance of the water caused by the passage of ships through shallow water. It is two hundred feet long, and simply a plain wooden bottom, an inch thick, made in sections about 5 by 8 feet, and secured to steel beams which are heavy enough to hold it down. It is arranged so that we can put it in place in two days and take it out in one day.

We have had other experiences with false bottoms, and we find, in towing these models, that a model which has a resistance of only a few pounds exercises a very strong upward suction on the bottom, when it is close to the bottom. We found it necessary to use 15-inch I-beams, quite stiff, placed 10 feet apart, so as to make sure that the bottom does not rise up and attempt to meet the model. The upward suction upon the bottom, resulting from a comparatively small horizontal pull, is surprising. This is caused by stream-line pressures, which are balanced as regards resistance, but by no means balanced as regards suction on the the bottom.

Mr. Stevenson Taylor:— I move a vote of thanks to Naval Constructor Taylor for his interesting paper.

The Chairman:—Gentlemen, you have heard the motion. I am sure there is no objection. Those in favor say Aye; opposed, No. It is a vote, and the thanks of the Society are extended to Mr. Taylor.

The next paper on the program is by a gentleman to whom we are indebted for a great many valuable papers, and this is a further favor to the Society. We will now have the paper entitled, "Resistance of Bilge Keels," by Professor C. H. Peabody, Member of Council.

Professor Peabody presented the paper.

RESISTANCE OF BILGE KEELS.

By Professor C. H. Peabody, Member of Council.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

The experimental boat Fulton, belonging to the Massachusetts Institute of Technology, was used during the past summer to investigate the resistance of bilge keels, for which purpose the boat was exceptionally adapted, both because the apparatus on the boat permits of the determination of small variations in resistance and because the prototype, the U. S. Navy tug Sotoyomo, after which the Fulton was modeled, was investigated by Naval Constructor D. W. Taylor, U. S. N., at the Washington Model Basin, and her stream lines were reported by him in the Transactions, Vol. 15, page 1.

The stream lines for the Fulton, properly reduced from those of her prototype, were laid out on her hull while she was hauled up in the spring and are represented on Plate 13, together with the various bilge keels used for experiment. The stream lines shown are for 6 knots speed of the Fulton, corresponding to 10.31 knots of the prototype.

After a careful study of the stream lines on the hull, and a consideration of the customary way of applying bilge keels, it was decided to take for the normal bilge keels a length of 15 feet and a depth of 3 inches. All the keels were three-fourths of an inch thick, made of oak and through bolted to the hull. They were set approximately at the middle of the length.

In order to get fuller and more certain indications of the effect of bilge keels, the depth of the keels was doubled and trebled. In addition experiments were made with the 3-inch keels abnormally extended toward both bow and stern; these extensions were both 2 feet long, giving a total length of about 19 feet.

The depth of the keel was doubled by bolting an additional 3-inch strake through both the normal strake and the planking, and the depth was in like manner trebled by bolting a third 3-inch strake outside. When the boat was fitted out the bare hull was given two coats of anti-fouling paint and keels 9 inches deep and 15 feet long were fitted as described, properly painted. As the experiments proceeded the extra strakes were cast off by driving out the bolts which secured them, plugging the holes with wood. After the double and treble depths of keel were cast off the boat was hauled up and the bow and stern extensions of the 3-inch keels were fitted. Experiments were made with extensions at both bow and stern; afterwards the stern extensions were cast off and experiments were made with the bow extensions only. The keels in all cases were faired down to sharp edges at both ends to form fair waters 2½ inches long. Where the bow

and stern extensions were fitted these fair waters were cut away so that a square butt joint could be made.

After the bow and stern extensions of the 3-inch keels were tested and cast off, the fair waters were replaced at the ends of the normal 3-inch keels, thus restoring the boat to the original condition. Experiments were now repeated on this normal 3-inch keel and finally, after it was cast off, the experiments made for the bare hull. Our previous experience had shown that the surface of the hull, once properly painted, would stay in good condition throughout the season in the Charles River Basin, consequently the surface was not changed in any way, not even when the boat was hauled up to apply the bow and stern extensions of the keels. Experiments with the normal 3-inch keels before and after hauling out and comparison of experiments with the bare hull as made this year and last year confirm this conclusion.

The resistance of bilge keels under normal conditions is but a few per cent of the total ship's resistance and is determined by the differences of resistances with and without keels; consequently the utmost care and refinement of experimental methods are necessary. The apparatus on the Fulton is that described by the writer in an article to be found on page 87, Vol. 19, of the Transactions; with care and skill this apparatus can be made to yield the necessary degree of precision for the work in hand, as will be made evident by the diagrams which show the original observations. It is proper to say here that the success of the year's work depends directly on the skill that has been developed by Professor Harold A. Everett, both in choosing suitable weather conditions and in watching and using the apparatus. His experience convinced him that only perfect weather conditions would enable us to get the certainty and precision needed for this work and that perfection of condition was seized when it came, whether by day or by night—very commonly at 4 o'clock in the morning. He was assisted loyally and intelligently by Mr. J. P. Constable.

The course for the experimental runs was about 200 feet off the northwestern sea-wall of the Charles River Basin, abreast the new location of the Institute of Technology. It is marked by small can buoys and land marks have been selected to aid in steering a straight course. The ends of the course this year are marked by certain electric light poles on the parkway along the bank of the Basin; these formed our back-ranges and the fore-ranges were poles set on an iron fence on the sea-wall. At night the fore-ranges were lighted by lanterns hung on them; the back-ranges were regularly lighted by the lamps of the parkway. This course is just short of an eighth of a knot, quite sufficient for our purposes.

The observations during a run were:

1. The time on the course.
2. The thrust of the propeller.
3. The revolutions of the propeller.
4. The power input to the electric motor which drives the propeller.

Subsidiary observations were taken of the direction of the run, the direction and intensity of the wind and time by stop-watch.

The first three were recorded on the tape of our recording device described in the article of 1911; the fourth item was read by the second observer, who also attended the recording device and adjusted the thrust mechanism. As in all the preceding work on our self-propelling models, the boat was carefully kept at normal displacement and trim for all the runs and only the two observers were aboard at their proper stations during any run recorded. The writer was able to give personal attention to the work until the first set of experiments on the keel of triple width was completed and the results plotted, after which the responsibility for all of the work was transferred to Professor Everett.

The sequence of experiments was controlled by conditions as has been stated; it is convenient to consider them in the following logical order; the dates are given simply as a matter of interest:

1. Bare hull, August 15.
2. Normal 3-inch keels, July 28 and August 12.
3. Normal 6-inch keels, July 11 and July 18.
4. Normal 9-inch keels, July 9.
5. 3-inch keels, bow extension, August 7.
6. 3-inch keels, bow and stern extensions, August 2.

From the dates it appears that the most important work, namely, with the bare hull and with the 3-inch keel of normal length (15 feet), came late in the season, when the work had settled into routine and acquired the greatest degree of certainty.

One propeller was used throughout the season; it had a diameter of 30 inches and a pitch of 39⅜ inches; it was the third one of the series of three used in 1912, being selected as giving the most convenient conditions for running.

All the observations were plotted as they were collated with revolutions as abscissæ. A sample set of curves is shown by Plates 14, 15 and 16.

Plate 14 shows the speed in knots per hour for the two series of runs made on July 28 and August 12 with the normal 3-inch keels; as has been said, these runs were made before and after the boat was hauled out to attach the extensions to the 3-inch keels at the bow and stern. The boat was supposed to be in the same condition on the two dates; the curve justifies this assumption and shows further that work could be repeated with certainty. The small black points represent observations taken on July 28 and the circles show the observations taken on August 12. The curve will be accepted as representing the mean for each series of observations. The dispersion of points is caused by a slight current in the Basin, due to the wind that had been blowing, for none of the runs were made when there was a breeze that could have an appreciable effect. This matter will be discussed more fully hereafter.

Plate 15 shows the thrust as recorded automatically by the thrust and recording mechanism for the series of tests on August 12. The curve shown by this plate is accepted as the correct curve of thrust in pounds of the propeller shaft, for all the runs under all conditions, *i. e.*, for the bare hull and for all the various arrangements of bilge keels.

Plate 16 represents the observations of input to the electric motor in kilowatts on the dates of July 28 and August 12, black points referring to the former date and circles to the latter date. Diagrams for the other series of tests are as satisfactory and need not be reproduced. From curves like those of Plate 16 have been deduced the usual curves of power on speed as given on Plate 20. For this purpose the rating of the motor by brake tests in 1912 are accepted, because the motor and mechanism are in substantially the same condition and any possible change cannot sensibly affect the increments in power due to adding bilge keels.

Having offered sample diagrams and claimed for them the degree of precision demanded for the work in hand, it is proper to account for the dispersion of points on Plate 14 and to justify the application of the curve of Plate 15 even when the observed points show deviation from it.

The experience of former years having shown the ill effect of a breeze, only favorable weather conditions were accepted this season, with the breeze so light that it had no appreciable effect. Nevertheless there was an appreciable deviation of results obtained from runs back and forth over the course. Collation of all the series as in the following table shows that these deviations were caused by currents in the Basin due apparently to winds that had blown before the runs were made. These currents were very feeble and could not be detected by any of the usual methods of measurement, although they persisted eight to twelve hours after the wind ceased blowing.

TABLE I.

Currents in Charles River Basin Due to Previous Effect of Winds.

Date.	Direction of wind.	Direction of faster runs.	Total deviation of curves. Knots per hour.	Velocity of current. Knots per hour.
1	2	3	4	5
July 9.....	None	S	0.10	0.05
July 11.....	None	..	....	....
July 18.....	Abeam	N	0.10	0.05
July 28.....	None	N	0.15	0.07
Aug. 2.....	With	N	0.04	0.02
Aug. 5.....	With	N	0.12	0.06
Aug. 7.....	None	S	0.06	0.03
Aug. 12.....	With	S	0.18	0.09
Aug. 15.....	None	S	0.04	0.02

It will be seen that five of the days showed no perceptible breeze, and on one day the breeze was abeam; on the other three days there was a barely perceptible breeze. The third column of the table gives the direction in which the runs took the least time; for those experiments marked "With" in column 2 the faint breeze was in the direction of the faster runs. Column 4 shows the total deviation of curves drawn through points for runs back and forth over the course; to avoid confusion the separate pairs of curves pertaining to July 28 and August 12 are omitted from Plate 15. The last column of the table gives the current in knots per hour.

The curve of thrust of the propeller on revolutions shown by Plate 15 depends on the acceleration imparted by the propeller to the water acted on. It very clearly is independent of current so that all the points for runs back and forth fall on or near the curve, as shown on Plate 15. Making the usual assumption that the acceleration is proportional to the real slip (so-called) it appears that the thrust should vary slowly with the resistance, and since the resistance due to bilge keels is but of few per cent, it might be expected that a curve of thrust on revolutions once well located could be applied to all the various series of experiments. Such, in fact, was found to be the case for tests made on August 12 and August 15, all the points lying on or near the curve of Plate 15.

Plates 17 and 18 show examples of deviations of points from the accepted curve of thrust on revolutions for the bare hull and 6-inch keels. The record of the tests for bare hull show that when the observations represented by the points shown by double circles were taken a breeze sprang up and died down again; this may be an explanation of the relatively small deviation shown. Plate 18 is in a different condition, as there is deviation of points near the extreme end of the curve. The observed thrust curve for runs of July 9 on the 9-inch keels has been rejected as unreliable and the standard thrust curve accepted in place of it.

Having in mind that the thrust of the propeller was the most direct evidence of resistance due to bilge keels the thrust mechanism was overhauled thoroughly and watched with care. The first records for the 9-inch keels gave a fair curve which appeared to be acceptable, so the 9-inch keels were cast off; the curve for the 6-inch keels for runs on July 11 differed so far that doubt was cast on the records for both sets thus far tried. It was decided to reject those records for July 9 and 11; other records, such as speed and power, were found to be consistent and form part of the basis of this report. Thereafter the thrust mechanism was repeatedly overhauled and watched sedulously and gave consistent and satisfactory results except for the variations shown by Plates 17 and 18. Consequently I have no hesitation in offering the results of tests on the resistance of bilge keels based on the accepted curve of thrust on revolutions as shown by Plate 15 for all our series of experiments, even including those tests, such as for the 9-inch keels, for which the direct observations are unsatisfactory. I have the less hesitancy because the observations for power for all the series of tests are consistent and satisfactory and confirm the results based on our accepted thrust curve.

The several curves of propeller thrust in pounds on speeds in knots per hour for experiments on the bare hull and with the 3-inch, 6-inch and 9-inch keels (all of normal 15-feet length) as given on Plate 19 were constructed from the proper curves of speeds on revolutions and from the accepted standard curve of thrust on revolutions. The thrust curve is that shown on Plate 15, and Plate 14 shows the curve of speeds for the normal 3-inch keel. Plate 19 is consequently a résumé of all the experiments on the normal length keels.

Plate 20 gives the power input in kilowatts to the electric motor for all experiments on the bare hull and for keels of normal 15-feet length, derived from curves like those on Plates 14 and 16. From these curves and from brake tests made in 1912 the horse-power applied to driving the propeller shaft has been computed and also used as a basis of determining the effect of the keels.

The main dimensions of the Fulton are as follows:—

Length, load-water-line, feet	30.9
Beam, feet	7
Draught, mean, feet	3.25
Displacement, tons fresh water	9.6
Normal speed, knots per hour	6.4
Wetted surface, square feet	298

The bilge keels had the following lengths measured at the middle of the depth:

Three-inch keels	15 feet 2.5 inches
Six-inch keels	15 feet 4 inches
Nine-inch keels	15 feet 5 inches

The wetted surfaces, including edge (¾ inch), were as follows:—

		per cent.
Three-inch keels,	square feet 17.1	5.7
Six-inch keels,	square feet 32.4	10.9
Nine-inch keels,	square feet 47.8	16.1

The per cents given are those of the keel areas to the wetted area of the bare hull.

The bow and stern extensions of the 3-inch keels were each 2 feet long. The surface of all four was 4.5 square feet.

The most direct experimental determination of the resistance of bilge keels can be made from the increment of thrust of the propeller shaft, above that required for the bare hull.

Taking first the 9-inch keels, since we are dealing with small differences, we may deduce the following table:—

TABLE II.

Resistance of Bilge Keels.

Speed. Knots per hour.	Thrust, pounds.			Increment from fair curve.	Resistance computed.	Ratio.
	Bare hull.	With 9″ keels.	Difference.			
1	2	3	4	5	6	7
3.	41.7	46.0	4.3	4.5	4.0	1.12
3.5	58.2	65.0	6.8	6.0	5.3	1.13
4.	79.0	87.6	8.0	8.2	6.8	1.20
4.5	106.5	117.5	11.0	11.2	8.5	1.32
5.	146.2	161.8	15.6	14.5	10.4	1.39
5.25	176.0	196.0	20.0	16.4	11.3	1.45
5.5	221.0	245.0	24.0	18.5	12.3	1.50
5.7	166.0	290.0	24.0	20.2	13.2	1.53
5.9	307.0	329.0	22.0	22.0	14.1	1.57
6.1	339.0	359.0	20.0	24.0	14.9	1.61
6.3	365.4	384.5	19.1	25.8	15.8	1.63

The quantities in the second and third columns of the above table are read from the thrust curves for the bare hull and for the 9-inch keel on Plate 19, and the differences are set down in the fourth column. These differences naturally show some irregularities which I have ventured to fair out. Considering that it takes at least two pounds at the shaft to make it move, the fairing appears to be allowable. The frictional resistance of the keels has been computed for the several speeds by aid of the equation

$$R_f = fS\,V^n = 0.011 \times 47.84 \times V^{1.84}$$

and set down in column 6. Anyone who chooses may readily recompute with any other values of coefficient and exponent which he prefers; it will not change the general conclusions. The ratios of the measured and the computed resistances of the bilge keels give the conclusions that are to be drawn from this source.

A conservative conclusion from the evidence here presented may be:—

For a speed-length ratio of 0.7 or less the resistance of normal bilge keels may be computed from friction only. At larger speed-length ratios the resistance of bilge keels may be half again as much as that computed for friction only.

It is interesting to note that the areas of the normal 3-inch keels are 0.057 of the wetted surface of the hull and if the same values for f and n can be used, the frictional resistance is that fraction of the frictional resistance of the hull.

The surface of the fore extensions of the 3-inch bilge keels is 4.5 square feet or .015 of that of the bare hull. The frictional resistance at 6.0 knots may be computed as 1.35 pounds, which is less than the limit of accuracy of our thrust mechanism.

The curve of thrust on speed for the 3-inch keels with both bow and stern extensions as plotted was found to be hardly distinguishable from that for the normal 3-inch keels; at lower speeds it appeared to fall slightly below and at higher speeds to rise slightly above that curve; but the differences were easily within the limit of accuracy of our observations. Consequently our observations, so far as they give any evidence, indicate that the bilge keels may be produced so far in proportion as shown on Plate 13 without undue increase of resistance. It will be noted that the extension at the stern does not much interfere with stream lines, but at the bow the extension crosses the stream lines at appreciable angles.

The experimental determination of the power required to drive the Fulton with and without bilge keels is given in kilowatts input to the electric motor by the curves on Plate 20. It is immediately evident that these curves in general characteristics and distribution conform to the curves of thrust on Plate 19, and that consequently they confirm those curves, and in particular justify the thrust curves for the 9-inch keels. The curve for the 9-inch keels has been chosen as most convenient for analysis; inspection of Plate 20 shows that the conclusions drawn from such an analysis may be applied to the narrower keels and in particular to the normal 3-inch keels.

At the several speeds in column 1 of Table III the kilowatts input to the motor was read and set down in columns 2 and 3 for the bare hull and for the 9-inch keels. From the brake tests of 1912 the equivalent brake horse-powers were taken and set down in columns 4 and 5. These brake tests of 1912 were made at length and with suitable precautions; the motor and shaft were in substantially the same condition during the experiments of this season as when the brake tests were made; and no possible change of condition would have an appreciable effect on our conclusions.

The efficiency of the propeller was taken from tests made at the Washington Model Basin by Naval Constructor D. W. Taylor, U. S. N., on a 12-inch model of the propeller used. The real slip (required for use with the report of such a test) was found from the apparent slip on the assumption of a ten per cent wake. Had a larger wake factor been used the efficiency would appear to be smaller than here given; but no possible change in propeller efficiency would affect our conclusions to any considerable degree.

Multiplying the brake horse-power by the propeller efficiency gives the power delivered by the propeller as set down in columns 7 and 8 of Table III; the difference, set down in column 9, is shown as the basis of comparison with the power re-

quired to overcome the frictional resistance of the keels. This is equivalent to assuming a hull efficiency of unity for both the bare hull and the hull with 9-inch keels attached. Plausible assumptions concerning the effects of bilge keels on wake gain and thrust deduction might make appreciable changes in the differences here chosen as the basis for conclusions; but it has been considered best to abstain.

TABLE III.

Power for Bilge Keels.

Speed.	Kilowatt input.		Equivalent brake horse-power.		Efficiency of propeller.	Propeller horse-power.			Horse-power due to friction of 9″ keels.	Ratio $\frac{10}{9}$.	Ratio $\frac{9}{7}$.
	Bare hull.	9″ keels.	Bare hull.	9″ keels.		Bare hull.	9″ keels.	Difference.			
1	2	3	4	5	6	7	8	9	10	11	12
3.0	.60	.775	.55	.72	.71	.391	.511	.120	.037	3.2	
3.5	.88	1.10	.88	1.08	.71	.625	.767	.142	.057	2.5	
4.0	1.25	1.54	1.28	1.56	.71	.909	1.108	.199	.084	2.4	
4.5	1.77	2.16	1.85	2.30	70	1.295	1.61	.315	.117	2.6	
5.0	2.57	3.11	2.75	3.41	.70	1.825	2.39	.465	.160	2.9	
5.25	3.20	3.90	3.52	4.28	.70	2.465	3.00	.535	.182	2.9	0.22
5.5	4.21	5.12	4.65	5.75	.69	3.21	3.97	.760	.211	3.6	0.24
5.7	5.34	6.38	5.85	7.30	.68	3.98	4.96	.88	.231	3.8	0.22
5.9	6.45	7.65	7.38	8.74	.66	4.87	5.77	.90	.255	3.5	0.19
6.1	7.48	8.87	8.60	10.13	.66	5.68	6.64	.96	.280	3.4	0.17
6.3	8.45	10.00	9.70	11.30	.65	6.30	7.35	1.05	.306	3.4	0.17

The horse-powers required to overcome the friction of the 9-inch bilge keels have been computed by the equation

$$H_f = 0.00307\ VR_f$$

and set down in column 10, and the ratios of columns 9 and 10 are given in column 11. From this last column it appears that the power required to drive the bilge keels is two and a half to three and a half times that computed from the friction of the keels. The ratio is therefore more than twice that found from the thrust of the shaft on page 15. The discrepancy cannot be charged to error or uncertainty of observation or computations, but is presented as a real difference of results from our two methods of investigation.

Finally, for the higher speeds there is given in column 12 the ratio of the increment in power due to 9-inch keels to the power for the bare hull. If it be assumed that the increment for 3-inch keels is one-third as great as for the 9-inch keels (as appears probable from Plate 20) we may conclude that the power required to drive keels of the normal proportions may be six to seven per cent of the power for the bare hull. The same figure can be used directly for brake horse-power or for indicated horse-power, since the reduction factors for a given speed are the same for the bare hull and for the hull with keels.

Acknowledgments.—The following gentlemen, all of Boston, Mr. Henry A. Morss, Mr. Lewis A. Crossett, Mr. Frederick C. Fletcher and Mr. Herbert M. Sears, very generously provided for the expenses of this year, and Mr. Harrison Loring, Jr., sent a receipted bill for transportation; to all and to each I wish to record here my gratitude.

DISCUSSION.

The Chairman:—The paper is now before you for discussion, gentlemen.

Mr. William Gatewood, *Member:*—In connection with this paper I would like to say that it is my recollection from the results of the experiments in the Washington Model Basin on bilge keels for battleships that these results are not borne out, and that the power required is almost entirely that which can be attributed to friction.

Mr. Elmer A. Sperry, *Member:*—I think the paper is very interesting and there is one point in connection with Plates 19 and 20 which I would like to bring up. Of course we must realize that the actual speed under which this work is done is rather small, yet the upper part of these curves is quite significant. We see in both Plates 19 and 20 that the curves are tending quite rapidly to disperse, showing more relative resistance at this point than at the lower speeds. Now, were these curves projected up into commercial speeds we can only guess what would happen. We are just commencing to understand a matter in connection with resistance in air, of much more rapidly moving bodies than this, relatively; that is, the augmenting resistance due to eddies in corners. So it seems to me it might be well if Professor Peabody would tell us a little more as to how these bilge keels were attached, whether there was a fillet at the junction between the keel and the hull.

Naval Constructor D. W. Taylor, *Vice-President:*—Professor Peabody's paper offers some interesting data in connection with wake factors, and I should like to give a little

discussion on that point, based on his results. I have a diagram prepared. In Fig. A, this curve 1 (indicating on diagram)—these diagrams are, of course, a little rough—this curve 1 reproduces the curve of thrust upon revolutions in Plate 15 of the paper. The curve 2 is the estimated curve of resistance, not of thrust, of the Fulton, based on model basin experiments, at almost the same displacement, 9.3 tons against 9.6. Of course the slight differences of frictional resistance, etc., make it impossible to say that curve 2 is in every detail comparable with curve 1, but for an approximate comparison the difference between the two curves indicates the thrust deduction under the conditions of the experiment. This, as you see, is quite large, but we expect a large thrust reduction for a vessel of this type and of the single-screw type.

Fig. B I have reproduced in curve 1—this full curve here (indicating)—the observed curve of speed and revolutions in Plate 14 of the paper. The dash curve is a theoretical curve of speed and revolutions for a phantom ship, to adopt Mr. Froude's supposition; in other words, if we had a ship with the resistance shown in this curve and driven by the propeller, no disturbance being caused in the water by the ship, we would get curve 2 for the curve of speed and revolutions. As you will see, curve 2 coincides with curve 1 very closely, throughout a certain range, and then a little above 5 knots it breaks away from it.

Curve 3, on the other hand, is a curve such as is used in model work to obtain the wake fraction or the velocity with which the ship drags the water behind it. That is obtained by assuming that the propeller at the revolutions shown was advancing, not at the actual speed of the boat but at sufficient speed to produce the actual thrust shown here. The only natural and proper assumption is that the propeller advances through the water at this speed (indicating on diagram) and not the speed of the boat; in other words, there is a following current which makes the speed of the propeller through the water less than the speed of the boat through the water.

This curve of wake fraction shows the wake fraction or the speed with which the water follows the boat, expressed as a percentage of the speed of the boat. As you will observe, there is a moderate increase from 0.08 per cent to something over 0.12 per cent, and then a rapid falling off at the speed at which these two curves diverge. There is a reason for that, and I would surmise (perhaps Professor Peabody or Professor Everett could say whether it is the case or not) that it is due to the change in the wave just over the propeller. Somewhere in the neighborhood of 5 knots for this boat 30 feet long there would be a wave crest over the propeller, and as we increase speed we reach a condition where there is a wave hollow, and a natural result is a rapid falling off in the wake fraction and a corresponding reduction here.

Professor Peabody calls attention to the fact, and it is a fact, that in most of our experiments with models at the Model Basin we found the increase due to the installation of bilge keels not much, if any, more than that due to the friction of the added surfaces. That is generally the case; in fact, there have been cases where it has been hard to get a difference equal to the computed frictional difference. You may remember that in the classical experiments of Mr. Froude on the Greyhound, when he towed an 800-ton vessel, he found the same condition—that the resistance of the bilge keels was scarcely up to that of the friction. The probability in this case is that the bilge keels have some influence upon the propulsive efficiency. These very deep bilge keels have probably changed the flow of the water, so that there is some effect different from the natural resistance. We measure in the Model Basin simply the resistance of the model—this is a case where the thrust is measured.

But there is another factor present. There is a case of a United States battleship which some time ago was tried with bilge keels. The bilge keels were afterwards removed and the ship was tried over the same course, same displacement, same conditions as nearly as possible, and the ship took materially more power for a given speed with the bilge keels off —it was a matter of several hundred horse-power—and although the experiments were not of a high order of accuracy there was no doubt that there was more power taken when the bilge keels were off. That was something of a puzzle, but the answer, I think, is comparatively simple—the vessel did not steer nearly so well after the bilge keels were removed, and in running a trial, in trying to keep the ship to a straight course, they used more helm with the bilge keels off than with the bilge keels on. It takes only a very few degrees of helm to produce a very decided drag on the vessel and increase the resistance. It has occurred to me that possibly the use of a helm may explain some of the discrepancies in these experiments, as this boat was tried in open water and they necessarily had to use a helm to keep a straight course. That is a factor which is ignored sometimes, but not ignored by the contractors when they want to get the best speed on a trial trip. They always use a good helmsman and see that he uses as little helm as he can possibly get along with.

The Chairman:—Is there any other gentleman who desires to comment on the paper? If not, we will ask Professor Peabody to make such reply to the discussion as he cares to.

Professor Peabody:—The experiments were carried on here, not only with the normal bilge keel, but with a bilge keel which was three times as deep as a normal bilge keel, and that the reports are based upon an investigation of all our experiments, the actual computation having been based upon the deepest keel, namely, 9 inches, but the curves on Plates 19 and 20 will show, particularly on an average from one curve to the next, that whatever we could attribute as the increase due to the 9-inch keel could be assumed to vary in that proportion for the 3-inch keel. I believe that, even if my wording is not as good as I would like, that you get the conception.

Now we have found also that with the best work that we can do it is very difficult to determine the amount of resistance closely enough to assert, from the experiments on the 3-inch bilge keels only, that the resistance did or did not increase proportional to the friction. We put on the 9-inch bilge keels purposely so that we should be able to get a better determination. We also extended the bilge keels to make them long, some 19 feet long instead of 15 feet long; and I report no result, because we got no result; namely, we got practically the same thrust and power with and without these extensions to the bilge keel. If we compute the added resistance for the increment in length of the 3-inch bilge keel, we will find that amounts to about 1½ pounds, and our thrust mechanism will move with an increase of about 2 pounds, and so you will see that getting this result does not signify very much.

As to the question raised by Mr. Sperry, I may note that the prototype of the Fulton is the Sotoyomo, a navy tug, with an approximate speed of 10.3 or 10.4 knots per hour, and that the curves given on the several plates, which extend only to 6.5 knots, are in the proper relation, by the theory of similitude, so that these diagrams show the dispersion at the commercial rates. But I believe it to be practically impossible to propel the Fulton, with any development of power you can put into her, up to 15 knots. What the curves would do in that case would be difficult to predict, and not particularly useful.

There has been a question raised as to how the bilge keels were put on. They were made, as stated in the body of the paper, of good ¾-inch oak, and were bolted on without any fillet, which corresponds, as nearly as our scale would admit, with the ordinary practice.

Of course, we cannot produce any answer from the experiments as to the effect of ratio of beam and depth of the ship on the bilge keel for that ship, which were all made on one particular boat.

E. A. Stevens, Jr., *Member*:—Have you any information as to whether the resistance of bilge keels increased in proportion to beam overlength of the ship?

Professor Peabody:—I am sorry to say, Mr. Stevens, that our experiments did not shed any light upon that question.

I am exceedingly obliged to Mr. Taylor for the very interesting and important addition that he has given to our experiments from the work which he has in his possession upon the tests of the model of the Sotoyomo, and I will ask my colleague, Professor Everett, if he can state whether the wave did or did not come near the propeller at the speed indicated by the diagram.

Professor H. A. Everett, *Member*:—I can only speak from memory, Professor Peabody, but at about five knots my impression is that the crest was immediately over the propeller, and at our maximum speed we had not quite run away from the wave, and had not quite reached the hollow.

Professor Peabody:—Perhaps I may be pardoned if I state to the Society that the rule governing our experiment was that when everything was in proper working order, we excluded everybody from the boat except those who were in the actual charge of sailing it, Mr. Everett and Mr. Constable, and I consequently did not have the information myself which I am very glad to receive from Professor Everett.

I shall not make any comments upon this addition of Mr. Taylor, which I should be glad to study more at length when I have an opportunity, further than to express, as I have already done, my gratitude for his addition.

With regard to the test on battleships with and without keels, I am going to say that, having spent, as we have, a number of seasons on making progressive speed trials under ideal conditions, such as I believe have never been realized for tests of ships at sea, I am not at all surprised that any tests made upon a ship with and without bilge keels failed to determine anything about it. Having made some speed trials, and having had this experience, I am the more surprised that progressive speed trials come out as close as they do rather than that they are not better. I do not believe that this question can be solved in that fashion. The suggestion which has been made by Mr. Taylor, explaining how that may have happened to the particular battleship, is perfectly in order, namely, that the use of the helm would be likely to make a resistance which might be as great as that of a keel, but I doubt whether either of these actually was determined upon the speed trials which were made, even though they should be made with all the skill and care which the Navy Department is known to give to work of that sort.

As to his suggestion, however, in regard to the use of a helm upon the Fulton, I will not say that the helm was used very little on the Fulton, and with just about the same regularity.

In the cases which I have reported, we had all the tests made under the eyes of an observer who had spent four years in learning just how to run speed trials under ideal conditions, where the slightest variation which would throw an influence into the work was observed and could be checked from the collation of results after the tests were made. So I am sorry that we cannot attribute any of our defects to that source.

THE CHAIRMAN:—I am sure you all desire me to voice our appreciation of Professor Peabody's paper by extending to him the thanks of the Society, which I now do.

At the council meeting yesterday a committee was appointed to draw up resolutions of respect and sympathy on account of the death of our late honored Vice-President, Mr. George W. Quintard, and I will ask Past-President Taylor, who is on that committee, if he will kindly read the resolution.

MEMORIAL TO VICE-PRESIDENT GEORGE W. QUINTARD.

Mr. Stevenson Taylor presented the following:—

At the annual meeting of The Society of Naval Architects and Marine Engineers held in New York on December 11, 1913, it was noted that on April 2 last there passed to the higher life George William Quintard, in the ninety-second year of his age.

Mr. Quintard was one of the original members of The Society of Naval Architects and Marine Engineers, and due to his activity in the merchant marine of the United States, as well as his own strong personality and influence, he was at the outset made one of the Vice-Presidents of the Society.

He was annually re-elected Vice-President until 1911, when the additional office of Honorary Vice-President was formed, and he was duly elected as such, continuing until his death.

As long ago as 1847 he became identified with the well-known Morgan Iron Works of New York City, remaining there as one of the proprietors until the works were sold to John Roach, the noted shipbuilder.

In 1869 he took over the Quintard Iron Works and resumed the construction of marine engines and appurtenances as well as miscellaneous machinery.

In the Morgan Iron Works he built many engines and boilers of the vessels of the "old navy," and at the Quintard Iron Works were built some of the engines, boilers and appurtenances of the more modern naval vessels, notably the machinery of the battleship Maine destroyed in the harbor of Havana on February 15, 1898.

His activities were not confined to manufacturing. He was a steamship owner and a director in many financial institutions and railroads.

He also served his fellow citizens of the City of New York as Immigration Commissioner and as Park Commissioner, declining all other tenders of public office.

His unusual temperament, his charming manner and courtesy, and his untiring interest in all that concerned his many activities, more especially the iron works and steamship lines with which he had been so long connected, commanded the admiration and esteem of all who knew him.

The Society of Naval Architects and Marine Engineers deplores its loss and tenders to the bereaved family its sincere condolence.

THE CHAIRMAN:—I believe it would be a very fine courtesy, as well as a desirable thing, if a motion were made to adopt the report of the committee. I assume that such a

motion has been made. Those in favor will please say Aye; opposed, No. The ayes have it unanimously.

The Secretary will kindly transmit a copy of the memorial to the family of Mr. Quintard.

The next paper, No. 3, is entitled, "On the Possibility of Building a Large Passenger Liner that Would not under any of the Known Mishaps at Sea Lose her Buoyancy or Stability and Sink," by Mr. George W. Dickie. Unfortunately Mr. Dickie is too far away to read the paper himself, and the Secretary will read the abstract. After that is read, we will ask Mr. Gatewood to read the abstract of his paper, and as the two papers are so closely allied, they will be discussed together.

The Secretary read the abstract of Mr. Dickie's paper.

ON THE POSSIBILITY OF BUILDING A LARGE PASSENGER LINER THAT WOULD NOT UNDER ANY OF THE KNOWN MISHAPS AT SEA LOSE HER BUOYANCY OR STABILITY AND SINK.

By George W. Dickie, Esq., Vice-President.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

This problem has occupied the minds of many, if not all, prominent naval architects since the disaster that overtook the Titanic in 1912. A great deal of legislation followed this calamity, nearly all of which dealt with means of escape for everyone on board a sinking ship. In a smooth sea and with all conditions favorable it might be possible to handle and load 80 or 90 boats and, if they could remain in the vicinity of the disaster and intelligence had reached other ships within a radius of 200 miles, a large proportion or perhaps all of these boats might be picked up. In order that this condition be possible, however, we must assume exceptional conditions.

I am writing this paper on board the Congress, a new vessel on her maiden voyage from Philadelphia to San Francisco. This vessel was designed by myself for the passenger and freight service on the Pacific Coast and is to run between Seattle and San Diego, the principal stops en route being San Francisco and San Pedro, the port of Los Angeles. Changes in the laws relative to life-saving apparatus added about 25 tons to the designed weight to be carried on the boat deck of the Congress and, in order to maintain the designed stability, I had to increase her beam from 53 feet to 54 feet 9 inches, the boats being carried 35 feet above the load line. With passenger list full this vessel carries 850 people and, should it ever be necessary that they leave the ship during that part of her voyage north of San Francisco, I can hardly conceive of its being accomplished without serious loss of life. The ship itself, even with half the freeboard gone, would be so much safer and more comfortable than small boats or rafts that it is worth much thought, careful planning, some compromises and considerable money to accomplish the design of a hull which would not lose its buoyancy or stability when subjected to the known disasters of the sea and which at the same time would not be open to any serious financial or commercial objections.

The question of designing a ship that cannot be sunk by any of the known accidents which befall vessels at sea cannot be treated in a general way. The conditions are so varying in different types of vessels that the only way to handle the subject is to assume a certain type and work out the problem in its relation to the assumption, which is what I propose doing in this paper. I have taken a typical large passenger steamer of the following dimensions:—

Length between perpendiculars	800 feet
Beam, molded	90 feet
Draught, loaded	33 feet

With a coefficient of .64 these dimensions would give a load displacement of 42,130 tons. There would be a complete double bottom, the inner shell being 4 feet from the outer skin, extending from the fore peak to the after peak and up the sides to the lower deck, which would be 15 feet above the base line. The main deck would be 9 feet above the lower deck and the upper deck 9 feet above the main deck amidships and would extend parallel to the base line from frame 87 to frame 233. From frame 87 to the stem, this deck would slope down, touching the stem at a height of 26 feet above base, and from frame 233 it would slope downwards aft, touching the stern frame at a height of 27 feet. There would be 12 bulkheads extending from the inner bottom to the upper deck. These would be absolutely watertight, without doors or openings whatever, and would be spaced as follows, the frame spacing being 30 inches: No. 1, fore peak, frame 24; No. 2, frame 45; No. 3, frame 66; No. 4, frame 87; No. 5, frame 116; No. 6, frame 145; No. 7, frame 174; No. 8, frame 203; No. 9, frame 233; No. 10, frame 254; No. 11, frame 275; No. 12, the after peak bulkhead, the double bottom space being divided in the same manner. As the horse-power of such a vessel would not be less than 45,000, the boiler compartments and coal bunkers would, to a large extent, control the subdivision, and it will be noticed that I have provided four main boiler compartments, each 72 feet 6 inches in length. Each compartment is intended to take four double-ended Scotch boilers abreast, these to be 17 feet in diameter and with 8 furnaces each, giving 128 furnaces in all, or 2,800 feet of grate surface to develop 16 horse-power per foot, which would be easy with forced combustion. It will be noticed that the boiler compartments have a bulkhead at each end 16 feet from the main bulkhead. These bulkheads extend to the inner bottom and skin of the ship and are built strong enough to support the wall of coal between them and the main bulkhead. These would each have 4 coal bunker doors, one opposite each boiler. Each bunker holds 750 tons and as there are 8 of them the coaling capacity would be 6,000 tons, all of which runs out directly in front of the boiler it is to serve. These bunkers would be filled from either side through side doors 3 feet 6 inches square with triangular side pieces forming hoppers when open, thus insuring quick coaling. The amount of coal provided is sufficient for eight days' steaming at 45,000 horse-power.

I think it will be admitted that this ship could be considered safe from any injury to the bottom below the lower deck and that danger of sinking would arise from rupture of the skin above the lower deck and under the water line which is at the upper deck line. Such danger would arise from collision with another ship at such an angle as would cause penetration or through striking some stationary mass between the lower and upper decks, opening up several compartments to the sea as in the case of the Titanic.

Let us first consider penetration by collision. Here the damage would be vertical and might, if the striking vessel were large and nearly at right angles, penetrate quite a distance into the side of the vessel. I think, however, that such a disaster could not entail more than three adjacent compartments if near amidships, or say 219 feet 6 inches. What would be the condition with three adjacent compartments near the center of this vessel flooded? The capacity of one of these compartments would be 163,345 cubic feet, from which would have to be deducted the displacement of the boilers, less furnaces, tubes and combustion chambers, or 13,120 cubic feet. The coal capacity would also have to be deducted, for if half the coal were used the vessel would be 3,000 tons lighter and if the coal were all on board it would displace so much water, and for this we must deduct 52,000 cubic feet and also 1,740 cubic feet for a central watertight passage under the upper deck. This leaves 98,225 cubic feet or 2,806 tons for each of the three compartments that we consider may be possibly injured through collision, or 8,418 tons to be carried by new displacement. In order to provide the displacement for the condition described above, I would propose to fit what I would term a double upper deck, the upper member of which would be 5 feet 6 inches above the lower amidships and parallel to the base line between frames 66 and 254, at which frames it would rise 2 feet and follow the shear line to the stem and stern. In case of a collision cutting into the upper member of the upper deck the local damage would be confined practically to the depth of penetration and the width of the striking ship, as the space between these decks would be divided into very small compartments both transversely and longitudinally. As it is, we have between these upper decks 9,730 tons of displacement which, in case of three compartments being opened to the sea, would leave the upper member still materially above the water line. If the injury were near the forward end of the ship, the lower member of the upper deck extending downwards reduces the size of the flooded compartments and the displacement of the contents of the holds, at least 50 per cent would still further have to be deducted, while the upper member rising at frame 266 and following the shear line would provide sufficient displacement to trim ship till water could be introduced into the double bottom aft. These same conditions would apply in case of serious injury aft. It will be understood, of course, that all openings through the upper deck, such as boiler and engine casings and hold hatches, would be watertight structures for at least 16 feet above the load water line.

We come now to another form of disaster, the ripping open of the side of a ship for a considerable proportion of her length by striking the projecting edge of some obstruction under the water line. In case under consideration this might happen between the lower and the upper deck for a great portion of the vessel's length. The five large compartments would add 14,030 tons to the displacement, while the forward holds, assuming that the cargo occupied one-half the space, would add 3,800 tons more, and the after compartments, if they had to be flooded to trim ship, would add 3,400 tons, a total of 21,230 tons. This would sink the vessel 11.86 feet, or 6.36 feet above the upper member of the upper deck amidships, and she would

then draw 43.86 feet. This assumption is to the very limit of the possibilities, yet, for an unsinkable ship, it should be provided against in the design. Between the upper member of the upper deck and the shelter deck there should be no air pores or side lights, or if lights are fitted they should not be arranged to open and the glass should be cast around a wire mesh as a protection against cracking.

The objection that would naturally present itself to this type of vessel is the apparent waste of space between the upper decks. This space, however, need not be wasted. Forward of frame 66 this space is 7 feet 6 inches high, increasing to 12 feet at the stem, and could be utilized to receive stores of all kinds, the compartments being only open at certain hours for issuing the day's supplies. The space from frame 254 aft, starting at 7 feet 6 inches and increasing to about 12 feet in height, could be divided into cold storage compartments for all the different kinds of provisions. The space amidships, 5 feet 6 inches high, would form the sub-basement for the hotel part of the ship above. All ventilating ducts, salt and fresh water mains and drainage pipes would be arranged in this space so that only vertical piping would be carried to the rooms. This grouping of all piping and ducts which run horizontally would save much trouble both in the design and working qualities of these systems. This I consider a very important feature in such a design. One of the hardest problems the designer has to face is dealing with pipes and ducts through living quarters and it is always the horizontal pipes that give trouble. By having the mains of these systems between the upper decks where they are accessible at all times without the passenger knowing anything about them, a continued source of dreaded trouble is removed, and, furthermore, this would not interfere with the proper subdivision of the space.

Referring to the cross-section through one of the boiler compartments, it will be observed that I have provided a longitudinal passage under the upper deck. This passage would be extended through each compartment, from which it would be entered through an air lock, and it would extend from frame 87 to frame 233. In each boiler compartment on each side would be the living quarters for all the men engaged in that compartment. These quarters would be artificially lighted and ventilated. The air would be taken from ducts between the upper decks on the inboard side, discharge at the floor line and would pass up through ventilating pipes on the outboard side. It might be objected that these quarters would be hot in spite of good ventilation. In this connection I consider it quite unnecessary to have much heat in the boiler rooms. The boilers in such a ship would be worked under forced combustion, and in that case the fans for forced draft could draw the air from the outer casing round the smoke stack and uptakes and discharge it into a casing outside the boiler lagging so arranged that the air would circulate round the boilers on its way to the tubular heaters in the uptakes. Thus any heat radiating through the lagging on the boilers would be taken up by the air for combustion, leaving the fire rooms comfortably cool, and with cold air freely circulated through the living quarters they should be quite comfortable.

The air lock doors into the central passage would be self-closing, balanced doors, easy enough for a man to open but certain to close after him, and it would hardly be possible to conceive of any damage to this passage even from a collision with a very large ship. At both ends of this passageway would be stairs in a water-tight well leading to the shelter deck.

The compartment forward of the forward boiler compartment would contain the main ventilating fans with cooling and heating chambers for the air. These ventilating fans would be supplied from trunks extending well above the weather deck, and their capacity would be such as to insure thorough ventilation throughout the ship. The compartment aft of the main engine room would be the electric generating room, where a sufficient generating plant would be installed to insure perfect lighting, heating and ventilation.

I have not, of course, tried to work out all the details for such a ship. What I have done is intended to be suggestive. A vessel built to carry out correctly such a suggestion would, I am sure, be practically an unsinkable ship and, with all her fire mains controlled from the interior of the upper deck, it would hardly be possible for a fire to gain great headway. We have just heard by wireless that a fire had broken out on the Imperator in New York harbor. This would indicate another form of possible disaster to the great modern passenger liner. The double upper deck would offer many advantages in case of fire. The fire mains, probably six in number, would all be installed between these decks, and vertical pipes from these mains would extend up to every room, in size and number proportionate to the size of the room. By means of these numerous rising pipes, any room in the ship could be immediately drenched with water, and these pipes could be arranged to be operated either from the room where the fire occurred or from between the upper decks. By this means water would be applied only where there was fire and no damage would result outside of the place where the fire started. As a fire could not possibly occur between the upper decks and as this space is well ventilated, no part of the ship would be beyond direct control of the fire mains, and much of the unsightly attachments for fire hose in the living quarters could be done away with.

With a vessel so constructed would it be necessary to carry the great load of boats and gear for handling them that, under present conditions, is considered so necessary?

In bringing this subject before the Society, I do not wish to present it as a completely worked-out scheme. I would have liked very much to have worked the whole matter up in detail and presented complete plans of such a ship, but there has only been time for the simple presentation of the idea of a double deck immediately above the load water line and an arrangement of subdivision below that would permit of the displacement provided between the upper decks, rendering the vessel unsinkable under any of the known accidents that overtake vessels at sea. The more I think of it the more I am convinced that, along the lines I have indicated, a ship can be designed as a commercial problem that could confidently be considered as practically an unsinkable ship.

THE CHAIRMAN:—We will now ask Mr. William Gatewood to read his paper, No. 4, entitled, "Structure of Vessels as Affected by Demand for Increased Safety."

Mr. Gatewood read the abstract of the paper.

STRUCTURE OF VESSELS AS AFFECTED BY DEMAND FOR INCREASED SAFETY.

By William Gatewood, Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

In view of the general interest which has been taken recently in the subject of safety of travel by water, culminating in an International Conference on Safety at Sea, it was thought that a short paper in the Transactions of this Society touching on some of the problems involved would not be amiss.

The dangers of the sea in times past were so great that a safe return from a voyage was a subject of public thanksgiving. It is still so considered by many; but the progress in the arts of shipbuilding and navigation, and the safeguards provided in the way of lighthouses, etc., have rendered travel by water actually safer than travel by land.

There is, however, at the present time a demand for greater safety, and this demand for increased safety is natural, and is the indirect result of the advance in civilization. Human life was never considered so precious as at the present time. Look at the prominence now given to the prevention of disease, and compare it with conditions which prevailed a century or two ago. Look at the peace conferences and disarmament plans, at the employers' liability laws, and even at the courts, which are loath to condemn even murderers to death unless they are hardened criminals.

The natural tendency of the general public after any calamity involving great loss of life is to forget that absolute safety is impossible of attainment, and that the progress on which we pride ourselves cannot be made if the handicap is imposed that no risk of any kind shall be taken. The precautions which should be taken in any undertaking depend in great measure upon the disadvantages which are incurred concurrently with the precautions taken. For instance, if to insure the saving of one-half of the loss of life which occurs annually on our railroads, it were necessary that all passenger and freight trains should run at half speed, the public would not stand for the change, as the effect on the business and private life of the country would be considered intolerable.

Further precautions in connection with the safety of vessels would seem advisable then, only where they do not interfere so seriously with the present methods of conducting business and pursuing pleasure as to be considered a detriment to progress. The unsinkable vessel must be commercial, or it will find no place in the merchant marine of this or any other country. The problem that is presented at the present time is, therefore, to build vessels which shall be as safe as it is possible to make them, consistent with the requirements of their trade. In other

words, if further precautions in the building, navigation, and upkeep of vessels for the purpose of promoting safety are to be taken, they should be along such lines and so limited in extent that the commercial success of the vessels is not jeopardized. As the safety of vessels is a matter which is not apparent to the general public, it seems proper that it should be made the subject of national or international regulations as far as regulations can conduce to increased safety.

The dangers against which precautions should be taken in connection with the structure of a steel vessel may be classified as follows: Leaks, storms, ice, grounding, collision, and fire.

LEAKS.

Intact outside plating to above the water surface is such a common feature of new steel vessels that no comment on this subject is needed; except, perhaps, that the government should require that the outside plating of old vessels should be subject to examination at intervals and should be kept up to a certain standard of strength and tightness, and that underwater openings should be properly protected.

STORMS.

The precautions against storms should include the elements of strength, watertightness, stability, and control.

Strength.—The rules of the classification societies are based partly on experience and partly on theory, and in general may be said to provide ample strength of structure. Indeed there are many instances of vessels in service which have scantlings much below the standard of the classification societies, and which have shown no signs of weakness. It is generally accepted that if this matter is covered by legislation in this country, a suitable method would be the assignment to every vessel of a maximum load line which should be determined from a consideration of the scantlings of the vessel and her route in service. It is suggested that this maximum load line could be lowered as the age of the vessel increases, in a similar manner to the reduction of pressure on a boiler, to allow for deterioration. The stresses in the structure of a vessel seem to increase rapidly with increase of draught and displacement, and although the amount of the stress would depend on the shape of the vessel and the distribution of the cargo and other weights, it is considered that no fairer method of obtaining the measure of precaution as regards strength of structure to weather storms can be devised than by what is known as the assignment of freeboard.

To illustrate the effect of increase in draught, the case is presented of an oil tanker, 389 feet x 49¾ feet x 30 feet. When loaded to a draught of 20 feet, displacement 8,720 tons, the compressive stress in the upper deck figures out at 6½ tons per square inch in hollow of wave 385 feet x 19¼ feet. When loaded to a draught of 24 feet 3 inches, displacement 10,705 tons, the corresponding stress increases to 9⅛ tons per square inch, or an increase in stress of 40 per cent for an increase in draught of 21 per cent.

Freeboard must also be considered in connection with stability and in case of damage.

Watertightness.—Under this heading would come not only the tightness of the underwater plating, but also the tightness of the plating above water, of the decks and erections, and of the openings in the sides, decks, and erections. No special precautions in addition to those usually taken would seem necessary except the prohibition of the use, while under way, of openings which would be submerged in damaged condition.

Stability.—This is affected so greatly by stowage of cargo, etc., that a vessel which has a large measure of initial stability leaving port may have no margin of initial stability at the end of the voyage. Indeed, the introduction of water ballast is not an uncommon expedient adopted on many vessels, to compensate for the fuel used. Some very successful vessels are unstable when light, and have ample stability when loaded. To provide for a proper amount of stability by legal enactment would seem almost impossible, especially if possible damage is considered.

As illustrating the difficulty of making any regulations regarding the stability, there is instanced the case of a passenger steamer which, while light, was sunk in shoal water, as the result of a collision. The openings were patched and the vessel was ready for pumping out, when the question arose as to what was likely to happen during the process. The curves in Plate 24, marked "no ballast," show that the vessel would have been stable when first afloat at 30-foot draught, but would have become unstable as more water was pumped out and the draught was reduced to 18 feet or less. It was decided, therefore, to put ballast on board, as low in the vessel as possible—some 476 tons were added—and the curves in Plate 24 marked "with ballast" indicate that under such conditions there was no lack of initial stability at any intermediate draught.

Figure 2, Plate 25, shows the level of the water inside this vessel when the draught was reduced to 25 feet. It shows also the relative position of the metacenter and center of gravity. That the vessel would have so large a measure of initial stability in this condition, with the holds and machinery spaces flooded, was hardly to be expected.

Some photographs were taken of the vessel just after the collision, and the large list at one stage of sinking indicates that without ballast the lack of stability was far from being imaginary.

Control.—Suitable steering gear is so necessary that considerable attention is given to the subject in the design of all vessels. While accidents due to lack of control are frequent, it is doubtful whether anything would be gained by any departures from the recognized appliances.

Cases of loss of control of a vessel by derangement of the machinery are not infrequent, but are so much less frequent than formerly that this particular advantage claimed in former years for twin screws is nowadays not much discussed.

ICE.

Special provision is made in the structure of vessels which are expected to run through ice by means of special framing and plating forward near the water line. Contact with icebergs is a special case of collision, or, as in the case of the Titanic, it may be described as a case of side grounding.

GROUNDING.

This is one of the most common dangers from which vessels suffer. In many cases, when the ground is soft, no serious damage is done. But it does not seem feasible to design a vessel so that the bottom plating shall not be punctured, or the stern frame broken when the conditions are not so favorable. The amount of leakage into the vessel can be reduced by subdivision into watertight compartments, and the problem which is presented is how best to effect sufficient subdivision without too much cost and without interfering with the service of the vessel. The fitting of an inner bottom for the purpose of storing water for feed or ballast, and recently for the stowage of oil fuel, serves as the most desirable type of subdivision. As bottom damage often extends to the bilge beyond the limits of the standard double bottom, the extension of the double bottom to the upper turn of bilge, now not infrequent, affords an additional safeguard. But while accidents due to grounding often cause the loss of vessels and of their cargo, in remarkably few cases would loss of life seem to be involved.

COLLISION.

This source of danger is probably the cause of the majority of fatalities incident to travel by water, and means for minimizing the effect of collision are being given careful consideration by the maritime world, as the result of the loss of the Titanic. Collisions occur in so many different ways that it is difficult to decide what precautions will be effective in every case. Until the collision of the Titanic with an iceberg, it was generally considered that if a vessel would not founder with any two compartments open to the sea, that vessel would be extremely safe. The number of vessels of which so much can be truly stated is very small.

The safety of cargo vessels does not need governmental regulation, except only in so far as the safety of the crew is concerned, as all questions relative to the safety of the cargo will be settled by the shipowners and underwriters to suit the demands of trade. It is probably true that the precautions which should be taken for the safety of the crew do not need to be as great as for the safety of passengers, for reasons which are chiefly economic. The advantages of not handicapping trade are so great, that the taking of risks by the people engaged in any trade is accepted. In all building operations there is a loss of life for every so many dollars spent, and while this is to be regretted, there does not seem any remedy which will prevent accidents entirely, except a complete cessation of work

—and that is no remedy. The precautions which should be taken must be such as will not handicap the business unduly—and what is considered proper to-day, in the present state of the arts and of public opinion, may hardly seem sufficient a few years hence. The advancement which has been made in ocean navigation in one century shows that many of the risks of former days have vanished. The increase in the number of lives involved in any one accident is the real reason why, at the present time, additional precautions are considered necessary.

It is suggested, therefore, that the basis for further precautions in the structure of vessels should be the number of lives involved; and further, that greater precautions should be taken for the lives of passengers than for the lives of an equal number of the crew.

Protection of the propelling machinery, which prevents loss of control of the vessel, would seem to be of next importance to protection from foundering. Double bottoms under machinery spaces to afford protection in case of grounding, and, on vessels carrying a large number of passengers, wing compartments to afford protection in case of collision, would seem in order.

Protection from foundering in case of collision would seem to be obtained in proportion as a greater or less length of a vessel's side could be open to the sea without endangering the buoyancy or stability. Double bottoms would be of little use for this purpose. Watertight decks near the water line in intact condition would seem of no great benefit, as the damage would probably extend both above and below this deck; and, in most cases, they would seriously interfere with handling cargo. A fore-and-aft bulkhead at the center line would help to preserve the buoyancy, but would probably destroy the stability. Wing bulkheads spaced far enough from the side to be safe from injury by collision would be prohibitive in handling ordinary cargoes, and could be adopted with advantage in special cases only. Subdivision by transverse bulkheads is, therefore, the logical precaution to take. It is structurally simple, and transverse bulkheads interfere very little, if at all, with the handling of any kind of cargo, provided they are considered in the design of the handling appliances. Even lumber vessels can be built with numerous transverse bulkheads.

If it is determined that a vessel carrying a certain number of passengers and crew shall be safe from foundering with a certain proportion of the length of the side open to the sea, and it is attempted to obtain this result by transverse subdivision, the accompanying diagrams, Figs. 3-11, Plates 25-29, will give an idea of the conditions which will exist as calculaed for a hurricane deck coastwise passenger vessel. The vessel considered is 370 feet long from stem to propeller post, 49 feet 6 inches beam, and 35 feet deep to hurricane deck. The collision bulkhead is located at 6 per cent of the length of the vessel abaft the stem and the forward bulkhead of the machinery space is 46 per cent of the length abaft the stem. The vessel was assumed under two conditions of loading, one to give a draught of 18 feet 6 inches and the other to give a draught of 24 feet.

The conditions as to draught and initial stability were first determined with

the fifth part of the length of the vessel abaft the collision bulkhead open to the sea, considering the void spaces in the hold as 50 per cent. It will be noticed that for each condition of loading, the freeboard at the collision bulkhead must exceed 25 per cent of the draught, and the after bulkhead of the flooded compartment must extend above the load line, more than 18 per cent of the draught.

With the fifth part of the vessel's length forward of the machinery space open to the sea, the height of the forward bulkhead of the compartment must exceed 19 per cent of the draught, and the height of the forward bulkhead of the machinery space must exceed 13 per cent of the draught above the load line. This condition is not shown in the figures.

With two-fifths part of the length of the vessel abaft the collision bulkhead open to the sea, the freeboard at the collision bulkhead must exceed 65 per cent of the draught, and the forward machinery bulkhead must extend not less than 30 per cent of the draught above the load line.

Initial stability seems satisfactory in all the conditions considered, but it must be remembered that the void spaces in the vessel are assumed to constitute 50 per cent of the total, and this assumption will not be correct for vessels when carrying a small amount of cargo, or where the cargo is of great density, such as steel, iron ore, etc.

On this vessel, therefore, under the assumed conditions, transverse bulkheads spaced as shown, and extending to the deck below the hurricane deck, would afford protection in case of collision opening any one compartment to the sea, with draught intact not exceeding about 23 feet. They would also afford protection in case any two compartments were open to the sea, with draught intact not exceeding about 18½ feet. To afford protection at greater draughts, the bulkheads, with spacing shown, must extend to the hurricane deck, and the limit of draught would seem to be about 24 feet in case of damage bilging two compartments.

If the bulkheads are spaced closer, dividing the forward hold, for instance, into three compartments instead of two, better protection will be afforded in cases of ordinary collision and of grounding; and three compartments could be flooded with the same degree of danger as is attended by the flooding of two, with the wider subdivision. Or, if it is considered that the damage will be likely to affect but two compartments, of length about 50 feet each, a greater load draught could be allowed for bulkheads extending the same distance above the keel. The interference with cargo handling and stowing would be appreciable, but not prohibitive.

If more than two-fifths of the length of a vessel is required to be flooded with safety, it would seem that the transverse bulkheads would need to be supplemented so as to divide the vessel into cells, and this would be commercial in special cases only, as mentioned above. In the case of the Titanic, about 30 per cent of the length of the vessel abaft the collision bulkhead was damaged, or 36 per cent in all.

FIRE.

While accidents by fire are more frequent on vessels at dock than while under way, it would seem that further precautions could be taken to prevent the starting and spread of fires than are taken on the average vessel. Completely inclosing the freight spaces by steel, including steel covers for hatches and ventilators, would seem proper on vessels carrying any considerable number of passengers. The elimination of a large quantity of wood and other combustible material from passenger quarters can be made in many vessels at small first cost, and in some vessels at a saving in cost. The traveling public which approves of steel railroad coaches will probably offer no objection to greater simplicity on vessels if it is accompanied by an assurance of increased safety.

DISCUSSION.

THE CHAIRMAN:—Gentlemen, the subject of the safety of vessels at sea is now before you, having these two excellent papers to suggest ideas in the discussion. We would like to hear from Mr. Robinson.

MR. R. H. ROBINSON, *Member of Council:*—Mr. President and gentlemen, I have little to say on the subject of these papers, except that in reading Mr. Dickie's paper I am impressed with the idea that his watertight deck is very much the same thing as was proposed by Mr. Marsden Niles, formerly a naval officer, who presented a paper before the Senate Committee at the time of the Titanic investigation, the only difference being that he wanted one of these decks to be on every deck level, and the result was very much exaggerated.

I cannot help but agree entirely with Mr. Gatewood in his belief that the amount of protection to safety should be proportional to the number of lives involved. It seems to me that the expense, for the safety of a ship, in a ship which carries only cargo, and in which the crew must naturally assume the risk of the trade, should be quite a different thing from the expense for protecting the lives of a large number of passengers.

I suppose practically all the ideas in these papers have been taken up by the International Conference that is now sitting in London, and I imagine that as a result of that international conference there will be certain laws proposed in America. It seems to me that this Society should take a very active interest in the preparation of any laws that may be proposed as affecting the building of ships, the design of ships, and the operation of ships. I have no doubt that the Department of Commerce will probably be charged with the preparation of these laws and will be glad of any suggestions from the Society, and I think the Society should take it on itself to offer its services in connection with that matter, because any laws that may be passed will be of very great importance.

There is one thing which nobody has touched on here, which seems to me in many cases would contribute very largely to the safety of ships, and that is the installation of a compressed air system. This is not a very difficult thing to do, particularly on a passenger ship, where there are numerous decks. Something of that kind has been put in several of our battleships, and it is a matter of great simplicity, as it can be combined with the fire protection feature and you can utilize the pipes, to a great extent at least, that are already in the ship, and I think it is a matter which is worthy of very serious consideration. Probably on a single-deck cargo-carrying ship it would not be easy to put in, but on a ship with several decks, where the pressures could be graduated from the bottom up, it seems to me such a large step toward a solution of the problem that it is worthy of very careful consideration. Mr. Gatewood's suggestion of the application of steel hatches for fire protection would tend to make this even more easy.

Prof. Herbert C. Sadler, *Member of Council:*—The whole question of whether a vessel will remain afloat or sink really depends upon our definition of safety. We must make certain assumptions, and I think the congress at present meeting in London will probably come to some conclusions that will represent the results of the experience of all the nations of the world, and so we may very properly take those as being the conditions that ought to be fulfilled by vessels in order that they may float under certain conditions of flooding.

The question is really a rather complicated one, because we can attack it from so many points of view. In any ship we have varying permeabilities, as it has been called—that is, when a compartment is flooded, that compartment may contain machinery, engines and boilers or cargo of different densities, or passenger accommodations. We can average up these permeabilities and make our flooding calculations accordingly. After we fix the permeability of different compartments, then we ought to allow a margin of safety, to be determined by the experience of people who are handling ships—naval architects and others—but the margin of safety must be fixed in connection with the permeability. Or, as has been done, we can assume the vessel will go down to the bulkhead deck under any conditions, and then arbitrarily vary the permeability according to the type or size and speed of the vessel. All these are factors which come into this question of flooding. The size of the vessel, of course, is also important, and in general a larger and higher speed vessel should have a greater percentage of freeboard than the smaller and lower speed type. From my own point of view I feel that it is the more rational thing to fix an average permeability in the cargo space and then allow a percentage of depth as freeboard, or a margin of safety line, below which the vessel should never go under any conditions of flooding.

With regard to the number of compartments, we must bear this in mind: a ship is built for commercial purposes, and therefore, if we lay down a set of rules as to subdivision, etc., that make it impossible of operation, the ship will not be built, and therefore it is an important thing to consider the commercial end of this question of subdivision. Vessels, I think, will naturally divide themselves into those which will remain afloat with one, two, or three compartments flooded, and if you come to a type where you are between the two vessels, the one or two compartment vessel, you can overcome the difficulty perhaps by having one compartment flooded and run the bulkheads up a deck higher, or if you have two compartments flooded, run the bulkheads one deck lower. I think with some such scheme as that we can work up practical vessels which could be operated commercially and still be reasonably safe.

With regard to the bulkheads themselves, it is absolutely essential, if you are going to put in bulkheads, to have them do their work, and I think, perhaps, more attention will be paid to the strength of bulkheads in the future than has been paid to this question in the past. There is no use putting in a bulkhead unless it is a real bulkhead.

Mr. Gatewood mentioned something about wing compartments. I think we should go rather slowly with reference to wing compartments. It is a question in my mind whether a wing compartment is of great value. It forms a second line of defense, but unless there are some means adopted to connect the wing compartment to the corresponding one on the other side of the ship, they may prove a positive danger—that is, the vessel may lose her transverse stability sufficiently to capsize, so that the longitudinal bulkhead is not, in my opinion, an added means of prevention of sinking, unless it is kept rather close to the ship's side itself.

Naval Constructor J. G. Tawresey, *Member:*—Both of these papers are by gentlemen who can speak with authority on the subject. There is one rather unusual circumstance in connection with the preparation of Mr. Dickie's paper, that should make it of special value to the Society; that is that the paper was actually written at sea where the conditions and the limitations, especially the limitations, are very real, very much more evident than on blue prints spread on a draughting board. Mr. Dickie's long experience—a lifetime spent in designing and building ships, both warships and merchant ships—qualifies him to observe these conditions.

I note that, leaving out some of the details, the broad conclusions in the papers are somewhat identical; both of the writers seem to take the view that has been taken in the Navy, that the effect should be to make the ship herself safe rather than to depend on boats; also the methods adopted are practically the only ones that can be adopted, namely, subdivisions by bulkheads, double bottoms, and by cellular compartments at the water line. In some ships of the Navy, the small compartments are confined more to the spaces at the sides of the vessel, whereas Mr. Dickie's paper seems to divide the whole space between the decks into small compartments.

We also note the reappearance of the center-line passage—Mr. Dickie's favorite center-line passage—but in this case he moves it higher up.

The question is: can the usages in commercial practice be modified to make a ship of this character satisfactory to the owners and to make it financially successful? I am rather surprised to find a man who has been so intimately connected with the merchant service proposing to sacrifice, unless he can find some way of using it which does not occur to me, so much space to protect the ship's buoyancy and stability. He has gone quite as far as a naval architect goes in designing a war vessel.

Naval Constructor D. W. Taylor, *Vice-President:*—I did not propose to mingle much in this discussion, but in reading Mr. Dickie's paper there was one thing which puzzled me very much. It may be a clerical error. You will observe in his plate he gives the longitudinal section of the ship, and that deck which slopes down at each end he calls throughout the upper deck. I was aware that in the mysterious systems adopted by classification societies the upper deck is never the highest deck, but did not know that it had got into the hold yet, and I am wondering whether there is not a possibility of some confusion as regards that matter.

I observe that Mr. Dickie's tendencies run largely to horizontal watertight divisions.

Apparently Mr. Gatewood scorns horizontal watertightness. I am glad Mr. Dickie has come forward with a design in which he relies so much upon the horizontal watertight compartments, because I have several times advocated in the past for some of these very large vessels the fitting of a watertight deck forward and aft. One of the great dangers after damage, forward or aft, is the pronounced change of trim, and if in any way you can confine the water horizontally, the change of trim is reduced. You avoid the necessity of putting water in at the other end. I have been met by the statement that it is not commercially possible to fit watertight decks. It would seem to me with these large liners—these very large vessels, there is in the neighborhood of the water-line a practical line of demarcation between the inhabited part of the vessel and the part of the vessel devoted to cargo principally, and it should be possible to make that line of demarcation watertight and to protect the integrity of the watertight deck by enclosures running up above the bulkhead line. I hope Mr. Gatewood will give that matter attention after consideration of Mr. Dickie's paper. Mr. Dickie has spent his lifetime in commercial work, and he would not advocate horizontal watertight subdivision unless he believed it commercially practicable.

Mr. Alden W. Welch, *Visitor:*—There is one point I would like to raise—one not generally familiar—and that is the use of the boiler flue gases of a ship as a protection against fires on shipboard. I believe this question has come up before the Institution of Naval Architects of Great Britain. It seems to me such a simple scheme that, if practicable, it is well worth developing; and I would like to know whether it has been considered by members of this Society. In port the flue of the donkey boiler can be used; therefore, there is protection always at hand. At sea the funnel of the main boilers would be tapped. The equipment in the Harker system, which is the British system, patented for this service, consists of a De Laval turbine driving a fan, and a combined washer and cooler which uses sea water for cleansing the gases, and then there is the piping, etc., for distributing the gases.

Flue gases consist of about 80 per cent nitrogen, something like 10 per cent CO_2, probably at most 1 per cent of the poisonous carbon monoxide (CO), and about 9 per cent of oxygen. As 15 per cent of oxygen is required to support combustion, flue gas is inert.

One difficulty, perhaps, is that flue gas is so light, being about 1.05 as compared with air. In the Navy, carbon tetrachloride has been used experimentally with some success and that liquified gas is about five times as heavy as air. Its action would, therefore, be much more rapid than that of flue gas under gravity conditions only; but by the use of a fan I do not see why the latter could not be blown into the hold as quickly.

Flue gas is always available, and its use for fire extinguishing purposes would not interfere with the operation of the ship as is the case when steam is used for choking flames. The flue-gas system is worthy of consideration.

Naval Constructor Joseph H. Linnard, *Member of Council:*—I note the statement in Mr. Dickie's paper as follows: "There would be twelve bulkheads extending from the inner bottom to the upper deck. These would be absolutely watertight, without doors or openings whatever." I think most of us who have been engaged in building ships, especially men-of-war, know the great desirability of avoiding the use of watertight doors or similar openings through bulkheads, that are supposed to be watertight. Such watertight doors, even though fitted originally with great accuracy, and when tested found to be in per-

fect condition, yet in the course of service, where they are apt to be left open for long periods, are frequently found when the emergency comes to be unworkable, or if workable far from watertight, owing to distortions that have occurred and have not been corrected. Therefore it has seemed to me that, if feasible, it is a very important point in fitting the transverse bulkheads, which, as has been remarked this morning, are the main subdivisions that appear practicable and to be made without undue expense. But particularly with reference to such transverse subdivisions in the machinery compartment it has been found difficult to preserve such absolute watertightness without any openings fitted with watertight doors. In fact, I was an ardent advocate myself of such methods of construction, and several of the warships of the Navy were fitted without any watertight doors in the transverse bulkheads in the machinery spaces. But experience has shown that the pressure of daily inconvenience overcomes the remote improvement in safety, and in the course of time I believe every one of those ships had watertight doors fitted into the transverse bulkheads in the machinery spaces. I think any consideration of watertight subdivisions that leaves out of consideration the tendency of the seagoing man to search for immediate convenience at the expense of ultimate safety has to be carefully considered.

Mr. E. H. Rigg, *Member:*—I am glad to hear Mr. Robinson suggest that the Society take an active interest in whatever is done in the matter of securing the maximum practicable safety for life and property at sea.

Our record shows that the Society has always taken this interest, at any rate as individuals; a glance over the contents of our Transactions will show many papers bearing on this great subject in one or other of its many phases.

Mr. Donald's paper in 1909 deals with freeboard and scantling regulation; this paper was concurrent with a complete revision of Lloyd's and other registry societies' rules.

We have several papers on bulkheads; two especially, by Professor Hovgaard, occur to me at the moment.

The recent activity of the Department of Commerce in getting data together prior to the International Conference on Safety of Life at Sea, at present sitting in London, is familiar to us all.

The next year or so promises to be full of unusual interest to us as naval architects, and I take it that Mr. Robinson's idea is that the Society should actively co-operate with the Department of Commerce in framing regulations to meet the demand for increased safety, because the members of this Society are well qualified, individually and collectively, to take such active part as may assist in shaping matters to the best interests of all concerned.

Mr. Robinson:—That is exactly what I believe in. (Applause.)

Mr. A. P. Lundin, *Member* (Communicated):—I have read Mr. Dickie's paper with much interest, and regret that I could not be present and take part in the discussion.

I admire Mr. Dickie's courage as regards his plan for an unsinkable and fireproof ship. I wish him every success in constructing such a ship and trust that, when it has been completed, it will stand thorough demonstration of the correctness of Mr. Dickie's theories. If actual tests prove them correct, I think that steamship operators and financial interests backing the "unsinkable, fireproof ship" enterprise should be willing to show their confidence by taking out no insurance on a ship of this type nor on its cargo. I believe that such a

show of confidence might tend to influence the authorities as well as the general public to consider ocean travel without lifeboat equipment.

It seems to me that it would be to the interest of safety at sea if—until the unsinkable, fireproof ship is really an accomplished and proven fact—shipowners and naval architects would give due attention to the quality and efficiency of lifeboat equipment and the handling of lifeboats in rough water as well as in a smooth sea; in other words, lifeboats should be provided which will stand being thrown against the ship's side without smashing and also make it possible to carry the requisite number of boats without encroaching unduly on the deck space, while representing less actual weight per person carried.

Here in the United States we have ships so equipped; for instance, some of the army transports. Formerly these ships of moderate size had lifeboat capacity (including rafts) for only seven to eight hundred people, while with their new, up-to-date equipment they can take care of two thousand people—*i. e.,* the full complement of persons carried—in practically the same deck space. The additional weight of the new equipment does not seem to have affected the stability of the transports, although they are old and narrow and were not designed originally for this added equipment.

Certainly the increased weight of really efficient lifeboat equipment is a mere bagatelle as compared with the increased weight of such a design as proposed by Mr. Dickie.

A most important factor in connection with safety at sea is that officers and crews of ships should be properly trained by actual drills in the handling and launching of lifeboats; therefore it is decidedly important that the equipment be as complete and up to date as possible in order to facilitate and encourage such drills.

It is all very well to say that lifeboat equipment will be of service only in exceptional cases, but we should also consider the great amount of use for small boats every day—whether the water be rough or smooth; for instance, in embarking or disembarking from ships which have to lie in open roadsteads, where there is no harbor; also in the work of cable-ships and fishermen.

As regards the added cost of such equipment, I think, where the question of safeguarding human life is involved, this is certainly not great when compared with the premiums paid for insurance on ships and cargoes.

Until by actual tests the contrary has been proven, I contend that it is advisable to have proper lifeboat equipment on the most modern passenger ships, even as the most modern fireproof buildings are still provided with fire-escapes, and my contention is upheld by the fact that shipowners, as well as owners of buildings, continue to insure their property.

The Chairman:—Is there any other gentleman who desires to shed additional light on this subject? If not, we will be glad to hear from Mr. Gatewood with any comments on the discussion that he cares to make.

Mr. Gatewood:—In reply to Mr. Robinson's discussion of the paper, I would like to state that it seems to be much more important to so subdivide the vessel that it will automatically take care of the buoyancy and stability of the vessel, rather than to depend on the pumping in of compressed air, which, under all circumstances, must be a matter of considerable time and of preparation.

It will be noted that Paper No. 4 is devoted primarily to the conditions which arise in the United States in the construction of vessels, and does not enter upon the wider discus-

sion of the Atlantic liners; but it would seem that a further subdivision of Atlantic liners carrying a large number of people, principally passengers, would be in order over and above the subdivision by transverse bulkheads. To obtain this subdivision, merely longitudinal bulkheads have grave defects, due to the destruction of the stability of the vessel; and the introduction of watertight flats or decks is open to objection on anything except a purely passenger vessel, on account of the difficulty of utilizing the spaces below this deck for the carrying of cargo, without great inconvenience. On the other hand, on the purely passenger vessel, it would seem to me that the introduction of watertight compartments, separate and distinct from the shell of the vessel (which could be formed by means of two watertight flats and two longitudinal bulkheads, near the center of the ship), to limit the amount of water which would enter in case of a collision (which, it seems to me, is the great danger to which these vessels are subjected), would be an advantage; but the scope of my paper hardly covered the transatlantic liners, so that this is only hinted at in the paper.

In reply to Professor Sadler I would state that it seems to me that the interest which the United States takes in the International Conference of Safety at Sea is not the interest of naval architects, but rather the interest of the passengers—the traveling public; and that it is to be hoped that our representatives will look at it from that point of view and insist that, in the case of those vessels where a large number of lives are involved, the greatest subdivision which is practicable shall be insisted upon.

In reference to the wing compartments which were recommended in the area of the machinery spaces, perhaps the paper is not very plain, but the object of these wing compartments was to protect the control of the vessel, not to prevent the vessel from sinking, as a vessel at sea which is not under control is in a very much worse condition than one which is under control. By maintaining wing compartments abreast of the machinery spaces it would limit the extent of the damage due to collision, so as to prevent it from interfering with the working of the machinery of the ship, a matter of considerable importance and value.

Naval Constructor Tawresey brought up the matter of the subdivision of the ships, as regards this subdivision being satisfactory to the owner. It has been advocated by some shipowners, one at least, that transverse subdivisions will be a help to the stowage of cargo, not a hindrance. If such is the case, then efficient transverse subdivision as advocated in Paper No. 4 should not meet with opposition on behalf of shipowners, except in so far as additional first cost is concerned.

Naval Constructor Taylor's remarks rather advocated horizontal subdivision by means of decks, but I think I have replied to this in connection with one of the previous comments.

Both of these papers are primarily related to the construction of the vessel, and not to the additional precautions which should be taken in connection with safety in case of accidents, as to the prevention of fire by means of flue gases or the question of preserving the lives of passengers by means of lifeboats.

Mr. Linnard's remarks relative to the protection of the anticipated subdivision by limiting the number of watertight doors and other openings, it seems to me, are strictly in order, and should be advocated or insisted upon wherever it is practicable to make such protection intact. That would be one disadvantage in a watertight deck—that it must have openings in it which must be capable of operation, and the consequent danger of their being left open when they are needed, when they ought to be closed and watertight.

Mr. Robinson:—I trust I was not misunderstood as recommending the substitution of compressed air for any other means of preserving the safety of the ship. I quite agree with Mr. Gatewood in everything he said about subdivisions, care in building, and other means of that character, for preventing the loss of the ship. It was not so long ago that we were told that the Titanic was unsinkable, and that statement had the force of considerable authority behind it. It did not prove to be true.

My recommendation of compressed air was purely on the basis of a simple additional safeguard—after you had taken all the proper structural precautions, that was the simplest thing you could put on to add to them.

As to its taking a long time to use it, it is the thing upon which the submarine boats rely almost altogether for most of their operations, and it takes but a fraction of a second to open a stop cock and a very few seconds for the air to come in and blow the water out. If the ship is designed, and the installation put in with that operation in view, I do not think it would take any great length of time to utilize the system.

Mr. Dickie (Communicated):—The discussion on my paper (No. 3), "On the Possibility of Building a Large Passenger Liner that Would not, under any of the Known Mishaps at Sea, Lose her Buoyancy or Stability and Sink," was of such a character as to render any reply on my part unnecessary except to express my appreciation of the very kind way in which my short paper was received by my friends in the Society who took part in the discussion.

There are some things, however, that were noticed in the discussion that I think it necessary to refer to. Naval Constructor Taylor was puzzled about the location of my upper deck, which is just about the middle of the ship's depth of hold. The upper member of this double deck, as I have shown it, is in the position of the upper deck on the vessel on which I wrote the paper. On that ship we have the poop, bridge and forecastle deck the full length of the vessel, below that the shelter deck, below that the upper deck with the main and lower decks below. In a vessel with six completed decks it may be wrong and misleading to name the third one below the weather deck the upper deck. In some of the new registration books a different deck nomenclature is used: beginning with the first deck above the inner bottom we have the orlop, lower, 'tween, middle, upper, shelter and promenade. In this case the depth to determine scantlings is taken from the base line to the upper deck and the half girth to the second or middle deck, while the main sheer strake is on the line of the upper deck.

Some objection was made to my proposed double deck on the score of weight. I admit that the extra weight where I have shown it is not a factor in the strength of the vessel, still both the upper and lower members of this deck need not be heavier than sufficient to give the stiffness required as a platform for the hotel part of the ship, as in the case of flooding no great head of water could ever come upon it. The added weight need not exceed 600 tons, a very small percentage in the displacement of such a vessel.

Mr. Robinson refers to something that nobody had touched upon, "The installation of a compressed-air system." I think that I was the first to use this system in the floating of a stranded ship. Thirty-four years ago the ship Jessie Osburn went on the rocks about eight miles north of the entrance of San Francisco harbor. The bottom was torn out of her and I bethought me of the possibility of floating her on air. The lower deck was tightened and well shored to the upper deck, on which I established a good-sized air compressor with a boiler to operate it. When all was ready the tugs took hold, the compressor was started,

and inside of two hours she was in deep water. It was somewhat rough in crossing the bar and, as the vessel rolled, we lost a good deal of the air, and this illustrates the weak spot in the compressed-air means of expelling water. In the case of damage by collision the injury usually extends both above and below the water-line, and where that is the case the compressed air cannot be applied. Where the damage is in the bottom the system is ideal.

Mr. Alden D. Welch suggests the use of flue gases as a protection against fire. He had in mind, no doubt, Dr. Harker's system, which is very effective against fire in holds. Flue gases, however, destroy life as well as fire and have been very effective against rats on ships, yet the water system of fire protection must be used in living spaces, and the system I propose gives a splendid opportunity to confine its use to the particular spot where a fire has started without causing any alarm in other parts of the ship.

The foregoing remarks cover the discussion as far as it relates to my paper. I have to thank the gentlemen who took part in it for their kind feeling toward myself.

The Chairman:—Gentlemen, I am sure you will all desire that the thanks of the Society be extended to the authors of these two papers, and in your behalf I extend your thanks to them.

A motion was then presented for consideration by Commodore J. W. Miller, Vice-President, relative to action by the Society in urging the passage of legislation connected with deepening the approaches to the Cape Cod Canal. As it was evident that opinion was divided on this subject the motion was withdrawn by the author.

SECOND SESSION.

THURSDAY AFTERNOON, DECEMBER 11, 1913.

Vice-President Mr. W. M. McFarland, called the meeting to order at 2.50 P. M.

THE CHAIRMAN:—Gentlemen, the meeting is now in order for business.

MR. LEWIS NIXON, *Vice-President:*—Mr. Chairman, I rise to a privileged motion and beg to offer the following resolution:

MEMORIAL RESOLUTION TO CHARLES HENRY CRAMP.

It is with deep sorrow and sincere regret that the Society of Naval Architects and Marine Engineers takes note of the ending of the long and useful life of Charles Henry Cramp, Honorary Vice-President of this Society.

In our generation no name has stood for higher attainment in our art. He aided more than any one man of our country the development of the metal ship and steam engine and boiler.

Almost alone for years he stood as a sturdy and determined advocate of the capacity of the American shipbuilder to produce vessels and machinery that in efficiency of and refinement of product, were the equal of those of any European country.

He takes an honored place in our affections and regards as having fought for an American Navy of American build by turning out under his management vessels the best of their class, and by drawing upon his mature knowledge and ripe experience, to give of his energy to educate public opinion in favor of American shipbuilding, and of the adoption of a continuous naval policy.

He was one of our charter members.

The Council moves the adoption of the following resolution:

"The Society directs that this expression of its profound admiration for the professional ability and the patriotic life work of Charles Henry Cramp, and our regrets that this life of great attainment in the shipbuilding art should have come to an end, be spread upon its records, and that a copy suitably engrossed be sent to his family."

MR. NIXON:—I move that this resolution be adopted by a rising vote.

THE CHAIRMAN:—Gentlemen, you have heard the resolution which has been duly seconded. Those in favor will please rise. The resolution is unanimously adopted.

The Secretary has the names of gentlemen who have been recommended for membership in the Society.

THE SECRETARY:—At a meeting of the Council just held, the following new applications for membership were received and favorably considered:

Members (1).

James H. Chalker, Captain, U. S. Revenue Cutter Service, Custom House, New York, N. Y.

Associates (2).

Andrew W. Carmichael, Assistant Naval Constructor, U. S. Navy, Navy Yard, Norfolk, Va.

William L. Rodgers, Captain, U. S. Navy, Naval War College, Rhode Island.

THE CHAIRMAN:—Gentlemen, you have heard these names recommended by the Council for election to membership as mentioned.

MR. FRANCIS T. BOWLES, *Past President:*—I move that they be elected.

Motion seconded and carried.

THE CHAIRMAN:—The next paper to be considered is No. 6, which is entitled "A Substitute for the Admiralty Formula," to be presented by E. A. Stevens, Jr.

Mr. Stevens presented the paper, and in connection therewith said: In Table 11, Plate 45, you will notice at the bottom that the Utah is mentioned twice, one time with reciprocating engines, the other with turbines. The one with turbines gives the actual results from the trial trip of this ship, while the one with reciprocating engines is on the assumption that this ship had been fitted with reciprocating engines and propellers of equal efficiency to the Delaware. The curves on Plate 32 for the Utah are from the data on Table 9, Plate 43. The indicated horse-power of this ship, as stated in the footnote on page 51, was taken from her effective horse-power divided by the propulsive coefficient of the Delaware, thus doing away with any error due to propulsive efficiency. I might also state that the degree of accuracy of the calculations is only that which can be attained on a 10-inch slide rule, as it would have been impossible, with the time at hand, to have accomplished this work in any other way.

A SUBSTITUTE FOR THE ADMIRALTY FORMULA.

By E. A. Stevens, Jr., Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

During the winter of 1906-1907 the writer served on a subcommittee of the Jamestown Motor Boat Committee, known as the Rules Committee, whose duty it was to formulate a rule for the rating of motor boats that were to participate in the races to be held during the Jamestown Exhibition.

At the suggestion of Mr. M. M. Whitaker it was decided to use a formula that would rate boats according to a speed determined from easily ascertained hull measurements, and rated power of their motors. This formula had to be of comparatively easy application, and involve no laborious calculations.

After some discussion the following formula was adopted:—

$$V = C\sqrt[3]{\frac{P \times \sqrt{L}}{D}}$$

in which V was the speed in nautical miles per hour; P the rated power; L the waterline length; D the displacement in cubic feet, and C a constant which for racers was 11 and cruisers 9.7.

The proposed races at the Jamestown Exhibition were not held, but this formula was used by the Motor Boat Club of America during its regatta of 1907. It worked out fairly well, but not to the satisfaction of all the owners whose boats took part in the races; it was, however, an improvement on the formula of the American Power Boat Association which was used the year before, where in some cases the scratch boat had to make an impossible speed in order to win.

DERIVATION OF THE FORMULA.

This formula was derived from the well known Admiralty formula as follows:—

$$\text{I.H.P.} = \frac{D^{\frac{2}{3}} \times V^3}{C} \quad \text{or} \quad V = \sqrt[3]{\frac{\text{I.H.P.} \times C}{D^{\frac{2}{3}}}}.$$

Now

$$D^{\frac{2}{3}} = \frac{D^{\frac{5}{6}}}{D^{\frac{1}{6}}} = \frac{D^{\frac{5}{6}}}{\sqrt{D^{\frac{1}{3}}}}.$$

As the length of vessels of similar models varies as $D^{\frac{1}{3}}$ length (or L) was substituted for this factor, which gives

$$D^{\frac{2}{3}} = \frac{D^{\frac{5}{6}}}{\sqrt{L}}.$$

Now substituting the above value of $D^{\frac{2}{3}}$ and taking C out of the radical we get

$$V = C\sqrt[3]{\frac{\text{I.H.P.} \times \sqrt{L}}{D^{\frac{5}{6}}}}.$$

As it is a known fact that at the higher speeds the power required to drive a ship of a given length at a given speed increases at a greater rate than the displacement, and in order to encourage heavier and more substantial construction in racing motor boats, and also to simplify the formula, $D^{\frac{5}{6}}$ was replaced by D, thus favoring the heavier boat on a given water-line length. This formula, with the exception that D was taken in pounds instead of cubic feet, was applied to several motor boats as shown in Table 1, Plate 35. The average constant here works out to be 42.9. In taking D in cubic feet instead of pounds C would therefore be slightly under 11. Several other boats were tried under this formula, but the results obtained were not used on account of the uncertainty of the data at hand. In fact the data on the boats given in Table 1, Plate 35, cannot be said to be absolutely accurate but the committee considered it sufficiently close to work on.

APPLICATION OF THE FORMULA TO STEAMSHIPS.

About a year ago it occurred to the writer that this formula might be used in place of the Admiralty formula with more accurate results, as length is taken as a factor in this new formula. It was applied to several vessels as shown in Tables 2, 3, 4 and 5, Plates 36, 37, 38 and 39. I. H. P. was used in place of P, and tons were used in place of cubic feet for displacement.

Table 6, Plate 40, shows the constants at different speeds as worked out for five torpedo-boat destroyers all of the same length and similar model but varying in displacement. From this table the curves of C in Plate 30 were drawn. The average value of C for these five ships was worked out, the curve of which is shown in the same plate, above those of the individual ships.

Table 7, Plate 41, shows the values of C at different speeds, of the Delaware, North Dakota and Utah; and Table 8, Plate 42, shows the value of C for the Marietta, Wheeling, Dubuque and Bancroft, from which data the curves on Plate 31 were drawn. Both Table 7, Plate 41, and Plate 31 show the difference between a turbine-driven ship and one driven by reciprocating engines.

THE NEW FORMULA COMPARED WITH THE ADMIRALTY FORMULA.

In using the Admiralty formula there are two things to be taken into consideration, namely, the displacement ratio and the speed ratio, both of which affect the value of the constant considerably, and to use this formula with any degree of accuracy great care has to be taken in choosing the proper value for the constant. If in calculating the speed of a new ship this formula is used, quite accurate results can be obtained by using the same value for the constant as that of a given ship of about the same size, providing the displacement and speed ratios of the two are

nearly the same. If either one of these ratios vary (even but little) the value of the constant will have to be adjusted or else a large error will result.

In using the new formula the same considerations hold good but not to the same extent; for example, if the displacement ratio should differ by about 10 per cent the value of the constant changes only a small amount, while the speed ratio may vary considerably within certain limits without hardly any change in the constant.

In order to compare these two formulas, Table 9, Plate 43, was worked out for the values of the constants in both the Admiralty and the new formula for the Delaware and Utah* at different speeds. These values were plotted and curves drawn as shown in Plate 32. Curves representing the mean values of these constants for the two above-mentioned ships were then drawn. The greatest variation of the curves of the individual ships from these mean curves occurs at a speed ratio of about .77 where it is 5.36 per cent for the Admiralty formula, while for the new formula it is but 1.08 per cent. The values of the mean curve of the constant in the Admiralty formula varies from 383 (at a speed ratio of .487) to 265 (at a speed ratio of .952). This represents a difference of 18 per cent from the mean value between these points, while the value of the constant in the new formula varies between these points from 7.74 to 6.865, which is only 6 per cent.

The data from these curves give, the writer believes, a very fair comparison of the relative accuracy of the two formulas. The error due to propulsive efficiency is done away with, while that due to difference in model cannot be very great, as the two ships are very similar in shape.

Table 10, Plate 44, shows the value of the constants in the two formulas for the Marietta, Dubuque and Bancroft, from which the curves on Plate 33 were drawn. Mean curves might have been drawn here but it is believed that their importance would not be as great as in the case of the Delaware and Utah, as these three ships vary considerably in model; besides this the propulsive coefficients of these vessels are not known.

VARIATION OF THE VALUE OF THE CONSTANT IN THE NEW FORMULA.

(1) For ships of the same length, but varying in displacement, the value of the constant seems to be greater for the heavier ship at the lower speeds, while at the higher speeds it is less than for the lighter ship; this is as shown in Plate 31.

(2) For torpedo-boat destroyers between the speed ratios of .8 and 1.9 the value of C decreases in almost a straight line as the higher speed is approached.

(3) Between the speed ratios of .4 and .74 the value of the constant falls in some cases while it rises in others as the higher value is approached. From .75 up this value drops, except in the case of very light high-speed motor boats as shown in Table 12, Plate 46.

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*The indicated horse-power of the Utah in this table is assumed by taking her effective horse-power at various speeds, and dividing it by the propulsive coefficient of the Delaware at the same speeds.

(4) At a given speed ratio the value of C increases as the size of the ship increases, as shown in Table 11, Plate 45, and Plate 34.

MATHEMATICALLY DEDUCED ASSUMPTION OF WHICH THE FORMULA IS BASED.

$$V = C\sqrt[3]{\frac{\text{I.H.P.} \times \sqrt{L}}{D}}.$$

By simple solution of the formula for values of its various terms it appears that for ships of

(1) Same length and displacement, power varies as V^3.

(2) Same length and speed, power varies as D.

(3) Same speed and displacement, power varies as $\frac{1}{\sqrt{L}}$.

CONCLUSION.

In all the tables except Table 9, Plate 43, the indicated horse-power for turbine-driven ships is taken equal to the estimated horse-power divided by .92.

Most of the data given here was taken from various articles in the Journal of the American Society of Naval Engineers and from the transactions of this Society.

In presenting this formula before the Society, the writer does not claim that it is an accurate means for estimating the speed of ships, but merely one that can be used with more accuracy for preliminary calculations in place of the Admiralty formula. It is also easy to handle and requires less judgment and experience in its application.

DISCUSSION.

THE CHAIRMAN:—This paper presented by Mr. Stevens on "A Substitute for the Admiralty Formula" is now open for discussion.

NAVAL CONSTRUCTOR D. W. TAYLOR, U. S. N., *Vice-President*:—This is the twenty-first general meeting of our Society, so I presume the Society may be regarded as having attained its majority, and I should like to note in connection with this paper what seems to be an appropriate circumstance. I believe this is the first instance in which we have had a paper presented to us by the son of a member from whom in the past we have had numerous valuable papers, and from whom, I hope, we will also have many more in the future.

Mr. Stevens, I think, has made a distinct improvement on the Admiralty formula. I also think it needs improvement. The trouble with the original Admiralty formula is that it deals with a question in which there are a number of variables involved, speed, power, dis-

placement, the proportions, dimensions, etc., and it is impossible to satisfactorily cover a question involving so many variables when, as in the Admiralty formula, you select only three—speed, displacement and power. Mr. Stevens has introduced the length, which is a very essential factor as to the power required for a given speed, and in that way I am sure he has made a distinct improvement. I think also it is an improvement to put the coefficient as the first power of the speed instead of as the indicated horse-power; that reduces the coefficient and makes less discrepancy between coefficients. The result, of course, is really the same.

As regards motor boats, I think Mr. Stevens is perfectly sound in using a semi-empirical formula which does not follow the law of comparison. For such fast boats, as you increase the displacement the resistance increases much more rapidly, and by the formula he chooses he takes some account of that fact. I believe for the ordinary type of vessel it would be more satisfactory to substitute for the square root of the length, the length itself, which reduces the formula again to one following the law of comparison.

The Chairman:—When the idea is to interfere with a good old friend like the Admiralty formula there should be some champions for it. Has it any friends at all? We have a family pride in having this son of one of our members bring out his first paper, and we want to have good discussion upon it, if it is possible.

Mr. E. H. Rigg, *Member:*—The Chairman asked if the Admiralty formula had not a champion. Mr. Taylor gave me the hint; he compliments the Society upon the fact that we have the son of one of our distinguished members presenting a paper. We must remember that the Admiralty formula was devised by our fathers long before naval architecture enjoyed the facilities that this generation does, and before the days of high sea speeds and experimental tanks; it has served a most useful purpose. We recognize its limitations, however, so that it is gratifying to have an improvement, which extends and increases its usefulness.

I would also like to draw your attention to the fact that Mr. Stevens makes use in his paper of the ratio which Constructor Taylor uses in his Manual—I refer to the displacement-length ratio. To my mind that constitutes a very important element in the accuracy of his formula. Moreover, it is good to see everybody working along a uniform line for technical expressions: if you study literature on any one subject, you will find you have to look out for expressions that are nearly the same thing, but not quite. It is gratifying that Mr. Stevens follows up one of Mr. Taylor's expressions.

The Chairman:—Are there any other remarks? Mr. Stevens, what has been said is so complimentary that I do not know whether you care to say anything in reply, except to express your thanks. However, you have the opportunity.

Mr. Stevens:—I wish to express my thanks to both Naval Constructor Taylor and Mr. Rigg for their remarks. This formula, as stated in the paper, was originated for the rating of motor boats. About a year ago it occurred to me it might be used in place of the Admiralty formula for calculating the speed of steamships, substituting the indicated horse-power for rated horse-power, and tons displacement in place of cubic feet. After working on

this for some time and comparing this formula with the Admiralty formula, there seemed to be so great a difference between the two that I thought it would be of interest to the Society.

Mr. Stevenson Taylor, *Past President:*—I move a vote of thanks to the author of the paper.

The motion was seconded, put to vote and duly carried.

RESOLUTION OFFERED BY MR. R. H. ROBINSON.

Mr. Robinson, *Member of Council:*—Along the lines I was speaking of this morning, I would like to introduce a resolution, as follows:—

"*Resolved,* That this Society communicate with the Secretary of Commerce and request that it may be represented in the preparation of any legislation or regulations that may be undertaken by that Department looking toward the definition or control of the construction and inspection of ships."

Mr. Francis T. Bowles, *Past President:*—Mr. Chairman, in seconding this resolution, proposed by Mr. Robinson, I take it that the subject has arisen in connection with the discussion of Mr. Gatewood's excellent paper which was read this morning. I feel that the naval architects and marine engineers are in this matter in a somewhat delicate situation, as they always are when it comes to providing themselves with additional inspection. We have, most of us, more than sufficient, but we also ought to realize that we have responsibility in the safety of vessels which we should not shrink from; and if we do not meet this situation properly, it is more than likely that we will be subjected to regulation and inspection of a very unpleasant character.

Whatever comes of the International Conference, it will surely result in some development of the inspection service in the Department of Commerce and Labor. Now I think that without reflection upon any one, even upon ourselves, we ought to recognize, and undoubtedly do, that that service needs reorganization. It needs some fundamental legislation which shall enable the Department of Commerce and Labor to employ both naval architects and marine engineers in their service. In my opinion, it is necessary that the whole system of inspection shall be increased in dignity and responsibility, and that the Department shall be authorized to prepare and enforce regulations which can be adapted from time to time to the necessity of progress.

I second Mr. Robinson's motion, and I hope that the Chair will invite further discussion of this important matter.

Mr. Stevenson Taylor, *Past President:*—I am in hearty accord with the purpose of the resolution offered by Mr. Robinson, but President Wilson in his message to Congress called attention to the fact that there is now in London an International Conference on the subject of Safety at Sea, and he further said that after this Congress had concluded its labors we should put ourselves in a situation to do certain things.

Under these circumstances I think we should not venture to offer our services until we know what has been determined by this International Conference.

I therefore move to amend the resolution offered by Mr. Robinson, changing the language to this effect—that if after the conclusion of the International Conference on Safety at Sea in London, the Council of this Society should deem it wise to offer the services of the members of this Society, that they will then be authorized to do so without calling a special meeting of the Society.

We must remember that among the official delegates to that Conference are Admiral Capps and Mr. Homer L. Ferguson, both very well known for their services in the past, and the ability with which they will consider any subject put up to them. I think it would be unwise to interfere at this time.

Mr. Robinson:—I have great deference for Mr. Taylor's judgment, but one of the purposes of my resolution was that the Society might be in the position of having tendered its services to assist the Department of Commerce in construing what the International Congress may have decided. I do not presume to say that this Society could do a better job than the International Congress in London, but when the Department of Commerce comes to construe what the International Congress in London did, and put it into the form for legislation, I am inclined to think that some assistance would be of value to them, and that it would be wise for us to offer it.

Mr. Taylor:—I did not so understand the nature of the resolution as offered by Mr. Robinson. If that is the purpose of it, there is no objection to it at all. Particularly is this true when it is considered that the International Conference may establish standards for trans-oceanic service, which our lawmakers may wish to adopt for our coastwise, lake, sound and river services, but which, because unnecessary, may be very detrimental. If this resolution only means that we shall offer our services to construe the demands of the Conference in reference to our own commerce, then I am heartily in favor of it.

Mr. Luther D. Lovekin, *Member:*—I am glad to see that the Society is taking an interest in this matter, as from my personal knowledge of the attitude of the Department of Commerce, I am quite sure that they will welcome any assistance from this Society. For eight years I went to Washington to assist them myself, and for eight years tried to get Statute 4433 repealed. It is the most ridiculous thing which ever appeared on the statute books of this country. It was put through Congress in the form of a statute, and misinterpreted by the Bureau of Supervising Inspectors, and as it stands now it is a disgrace to the engineering profession. This statute will have to be repealed before the book is really in proper condition.

Mr. William Gatewood, *Member:*—As I understand the matter, the instructions given to our representatives in the International Congress were to confine their attention strictly to oversea traffic, and they are not empowered, in any way, to consider the subject of coastwise traffic or interior traffic. Such being the case, it looks as though this country were more concerned in its own coastwise and river traffic, and therefore Mr. Robinson's resolution is strictly in order.

Mr. Bowles:—I would like to disclaim any construction of my previous remarks as reflecting upon the efficiency of our representatives in the International Conference.

I want to make it clear, that whatever the International Conference does, there is a job to be done by the Department of Commerce and Labor with reference to the ships to which these regulations will apply, on which they will need help. Mr. Gatewood has made clear that while the International Conference may not deal specifically with coastwise and inland traffic on the rivers of this country, it will place a moral obligation on such things, and the importance of this subject can hardly be exaggerated.

Mr. Robinson:—Perhaps the way in which I have the resolution at the present time is not quite complete, and with the permission of the seconder, I will modify it and resubmit it. I therefore submit the resolution again, as follows:

"*Resolved,* That this Society communicate with the Secretary of Commerce, and that its services be tendered to assist in the preparation of any legislation or regulations that may be undertaken by that Department, as a result of the recommendations of the International Conference looking toward the definition or control of the construction and inspection of ships."

Mr. Taylor:—That meets entirely with my approval, Mr. Chairman, and having given this subject some thought, and having taken care to investigate the effects of what might come out of this International Conference, I favor the resolution as now offered by Mr. Robinson.

Mr. Andrew Fletcher, *Member of Council:*—Would it not be well, in Mr. Robinson's resolution, instead of using the words "ships" to use the words "steam vessels?" I make this point, because one of the very serious things o the recent Seaman's Bill S 136 that has passed the House of Representatives largely affects vessels on the Great Lakes that are not ships, but very large steamboats; it affects steamboats right here in the harbor of New York very seriously, and I think that if the resolution states steam vessels, rather than ships, it would be more general and inclusive.

Mr. Robinson:—I think the substitute proposed would be covered by "vessels," I do not see why it should be "steam vessels," but rather should be any kind of vessels.

The Chairman:—Instead of being an inclusive term, steam vessels would be an exclusive term.

Mr. Robinson:—The resolution as it now stands is as follows:—

"*Resolved,* That this Society communicate with the Secretary of Commerce and the Committees of the Senate and House charged with such legislation, and that its services be tendered to assist in the preparation of any legislation or regulations that may be undertaken by that Department as a result of the recommendations of the International Congress, looking toward the definition or control of the construction and inspection of vessels."

Mr. F. L. Du Bosque, *Member:*—Suppose the Secretary accepts this, what will you do?

The Chairman:—As Mr. Gladstone would say, when that question was put to him, that is a detail to be settled later.

I want to call the attention of the Society to one thing—the Department of Commerce invites every naval architect in the country to come once a year to talk over things pertaining to his own business. I presume we have all had the invitation. Where does the resolution differ from the practice now prevailing?

I do not know, but I presume Mr. Robinson's idea is, if this is carried out, that the Council would arrange for the appointment of an appropriate, strong committee to be prepared to go down to Washington and as representing the Society to go over this matter with the Department of Commerce, not simply going over any regulations which may be prepared paragraph by paragraph, but probably in suggesting the legislation, getting it into shape, and submitting it to them.

Gentlemen, you have heard the resolution; all in favor say Aye; contrary-minded, No. The resolution is adopted.

The next business is Paper No. 9, "Construction and Operation of Western River Steamers," by Mr. Richard Clarke Wilson. In the absence of Mr. Wilson, the paper will be read by Mr. W. P. Stephens.

Mr. Stephens read the paper.

CONSTRUCTION AND OPERATION OF WESTERN RIVER STEAMERS.

By Richard Clarke Wilson, Esq.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

Since the able and comprehensive paper submitted to this Society at its Detroit meeting in 1909 by Mr. Charles Ward, in which full details were given of the construction and design of river steamers, there have been no changes from the prevailing types of boats, so that it is unnecessary for me to go into details of construction. I will confine myself to our handling of the boats and the business as it is done to-day, and as it has been done for many years.

With the exception of the tunnel propeller boats on the Missouri River, consisting of one packet boat, one towboat, one private yacht and one 61-foot launch, and the very successful fleet of river barges for use between the Alabama coal mines and New Orleans, and a few motor yachts, there has been no improvement in design with the possible exception of piping and valve gear of compound engines, and the advent of one or two types of boilers yet to be tried out, since their adoption by river steamers has been very recent.

Many accidents have occurred which could have been easily prevented by modern construction, and many fires have swept the boats which could have been obviated by steel construction, which has proven so valuable in preventing serious accidents in railroad wrecks. Many years have elapsed since the use of steel for steamship hulls became universal, yet to-day we are just beginning to recognize the superiority of steel over wooden hulls for river work. Many wrecks have occurred to wooden hulls and, within the last two years, one line has lost three boats and eighteen people by accidents, all of which would not have been serious with vessels built of steel. This same line has just built two boats similar to the three wrecked ones, with wooden hulls and houses.

We recently, at Lake Providence, had a large and well-appointed packet boat sink at the landing after running into but not damaging a wooden barge, and this same line, at that time, had a similar boat on the ways being repaired after encountering a snag, sinking and being raised. They also had the misfortune to lose by fire, within that same fortnight, the upper works of a steamer one year old, which boat had a steel hull.

Dozens of wrecks and accidents have occurred to such boats with "one partly watertight compartment;" which begin to leak when loading commences, and continue to do so until swelling of the seams that have dried out since laying

up. This expense seems never noticed in cost of operation, or it certainly would have been sufficient of itself to cause a revision of construction. Many tons of fuel are annually wasted by this cause alone, as also by pumping and the more wasteful siphoning of hulls that have been damaged by grounding or collision.

Iron hulls are, of course, more desirable, but this material is not now available for boat construction. The first iron hull built for river service in this vicinity was the John T. Moore, built at Cincinnati in 1871, and after use on the Red River, and the Alabama River at Mobile, and in the harbor of New Orleans as a Southern Pacific Railroad transfer boat, is now the flagship of the barge fleet of the Kansas City-Missouri River Navigation Co., and is named the Endeavor, good for several years of money-making usefulness.

We have lost some boats from overloading and other glaring instances of carelessness that should have been prevented. One packet overloaded at a sugar landing and, backing off in a fog, brought up on the opposite bank of the Mississippi River stern first, carrying away stern-wheel and rudders, when the use of a drift lead or sounding pole would have indicated that the boat had sternway.

Many of our boats have grown out of former wrecks and, directly opposed to eastern practice, where a hull has been known to have had three sets of boilers and engines looking to economy, we have several sets of machinery that have served on three or more boats.

One would think that, with the cost of operation steadily ascending, caused by scarcity and high price of labor, we would welcome any economy in the mechanical operation of the boats, but in many instances such is not the case. Since the contest in the harbor of Charleston, W. Va., several years ago between the quadruple expansion twin-screw tunnel steamer General Rumsey and the larger stern-wheel towboat D. T. Lane, in which the Rumsey was victorious in every test, there have been very few cases of the adoption of more modern and economical machinery, as such a demonstration as this should warrant. Photographs of this contest and full descriptions were published broadcast. An owner who feels keenly the increased cost of operating his stern-wheel fleet, recently remarked that he saw this article but was not interested in it.

One of our cross-compound surface-condensing stern-wheelers, built in 1889, and operating in a 110-mile tri-weekly mail route, saves $50,000 during her four years' mail contract over a sister boat of the non-condensing non-compound type, which latter is the prevailing and favorite type now in use.

Another $25,000 can be saved over and above this very favorable performance by using Diesel engines or gas producers, as has been demonstrated by the new barge line between Alabama and Warrier River points and New Orleans; their barges show a consumption of one pound of coke breeze per brake horse-power per hour. They carry from 800 to 1,000 tons coal on a draught of 6 feet to 7 feet, and operate with twin screws, using 75 brake horse-power on each, making about seven miles per hour loaded. We have boats now in use that use from 6 pounds to 9 pounds coal per horse-power (indicated) per hour, and their fuel is delivered along-

side at New Orleans by triple and compound tugs and is towed down from Pittsburgh by compound condensing towboats. Since for so many years the ocean and lake power has been developed with from one-third to one-fourth this consumption of fuel, we may readily look to our engine rooms for some of the losses that are annually augmented by labor charges and loss of time.

The satisfactory performance of the tunnel propeller towboat A. M. Scott on the Missouri River has been the cause of the U. S. Engineer Department ordering from Mr. Ward a sister vessel to replace the stern-wheeler Mississippi. The A. M. Scott has two 60-inch propellers, driven by triple-expansion surface-condensing engines. The four tunnel boats now in use on the Missouri River were not designed for service on that stream, which, in low water, is more nearly a flowing roadway. There are always details of construction that make a craft more adapted to certain localities. The tunnel steamer Chester was designed as a triple screw, with wing triple engines exhausting into a non-reversible low-pressure turbine, which should add about 400 indicated horse-power to this plant, but the boat has seen service for three seasons as a twin-screw packet boat, and the center propeller and the more economical turbine have not been installed. This installation will add about one-third more speed to the boat, at absolutely no additional fuel expense.

We found that, in shallow waters, much more power is required by any type of boat. A constant for this increase of power is not obtainable as in deep-water practice, owing to the constantly changing conditions of current and depth of water. On any paddle-wheel boat, perceptible and sometimes vastly apparent losses of power and speed occur when running into shallower water, but no tests that are available have been made. The stern-wheel steamer Advance, drawing 36 inches of water and pushing a barge about her own size drawing 48 inches, showed the following losses, during a recent test on the Missouri River. Soundings were taken at the engine-room door, and not on the head of the tow, a difference of about 200 feet. We find practically no loss of time or power with the tunnel boats, and no squatting or wallowing in extremely shallow water with 6 inches to one foot of water under the hulls.

TESTS FOR REVOLUTIONS, STEAMER ADVANCE.

Course upstream. Strong head current. Light head wind. Below mouth of Osage River.

Time P.M.	*Depth water Feet*	*Revolutions Per min.*	*Time P.M.*	*Depth water Feet*	*Revolutions Per min.*
1.28	18	24	1.33	15	21½
30	20	24	34	10	18
31½	17	21	35	7	15
32	18	24	36	10	21½
Slow from 1.36 to 1.56 P. M.					
2.03	13	22	2.13	14	19½
04	13	21	15	14	20
05	11	21	17	13	16
06	10	20	17½	11	15½
07	11	21	19	17	21
08	9	21	21	24	22
08½	7½	19	22	20	22
09½	10½	18	24	18	22
11	11½	19½	25	19	21½
12	13	21	33	20	24
Cut off one notch closer.					
2.35	14	21	2.46	7-6-5	13
37	7 to 8	15	47	4½ to 5	10½
38	8	14	47½	5	12
39	10	18	48	9	17
40	12 to 13	22	49	13	12½
44½	8	12	50	18	22
45	9	16	51	20	24
Slow from 2.53 to 2.59.					
3.00	8	15	3.06	14	18
01	15	22	07	11	17
02½	16	23	08	11	18
03	17	24	09	11½	18
04	24	24	10	12	18
05	18	24			
Slow 3.19½ to 3.30 west mouth Osage River.					
3.35½	9-10	16½	3.38½	9	18
36	7-6½	15	40	12-14-13	20
38	8	17½	45	15	22

Tests made with the steamer A. M. Scott in handling a tow descending the Kanawha River demonstrated the fact that flanking is not necessary with the tunnel type of boat, owing to its perfect steering when going ahead. This has been demonstrated several times by this steamer in descending the Missouri River, thus showing that the saving in backing up a tow to allow the current to swing it sideways to flank it out of a bend may be saved by the boat steering the tow out of the bend, thus many hours a trip may be saved by a towing fleet, with properly designed boats. Many accidents have happened at landings in flanking onshore, where a snag appeared after the sidewise movement of the boat began, and, with an onshore wind she is blown against the bank, as no control of the boat is possible without either headway or sternway, which accidents may be prevented by maneuvering with wing propellers on a tunnel boat. Damage from drift and logs is no more harmful to the tunnel propellers than to the stern-wheelers. The easy access to the propellers admits of as quickly replacing wheels or blades as repairs to buckets and wheel-arms require on stern-wheelers. The building cost of both types of boats is about the same.

Now the general idea is that boats descend rivers faster than they ascend them, but in the way we work them this is not the usual result. In ascending the lower rivers we take advantage of slack water and of eddies behind points, and make almost as good running time upstream as down. But, with the present type of boats, we are handicapped by not being able to go ahead on the engines and run out of a landing; if the wind is onshore, we have to back downstream and work our nose out to windward, thus straightening up and, in many instances, passing the same landing twice. One packet boat required twenty minutes to pass the foot of Conti Street, New Orleans, which landing she had just left. This waste of time occurs at many landings, so that, if a tunnel boat were to be used in the packet trade, a vast saving would result in upstream navigation.

In descending the rivers, hour after hour is lost, even in our best managed lines, as the boats have to round to and head upstream, since they can be handled only at one end in loading and unloading freight. In making the turn, much care is necessary, should the boat be deeply loaded, as she has to stop out in the river before making the turn and wait for her following sea, caused by the stern-wheel, to pass on downstream, so as not to cause working of the hull and washing of the deck. This requires different time in different current, and finally the landing is made with the bow upstream.

In leaving this landing, the boat is backed out and, in almost all cases, the backing around this half circle is done without cutting off steam, as many of the old-time engines cannot cut off when in the backing motion. From five to fifteen minutes are lost in maneuvering the boats at almost every landing made downstream, as from one-fourth to one-half mile backing is done under this great loss of steam, and from five to fifteen minutes' valuable time is consumed. Taking a smart packet boat as now, we have a loss of time and mileage of about 120 minutes in fifty landings and 10 miles' unnecessary run upstream, and 600 minutes

and 20 miles unnecessary backing downstream. As some of our boats make 100 landings upstream and about 60 downstream, two trips each week, we can save about one day in each week by having a boat that will make all landings with head downstream with a stern stage and gangway, taking freight and passengers over the stern. We would then have 52 more working days each year in which the fuel bill will be covered by the saving in waste and, as salaries, insurance, subsistence and overhead expenses are already paid, the only additional expense we would have in labor of handling the extra freight is also covered since this labor is carried on the boat and paid by the month.

These are facts as found in daily average practice. We have seen sufficient demonstration to believe that properly designed tunnel propeller boats would be hull down the first few hours out if leaving port at the same time as a similarly powered, manned and burthened stern-wheeler. The use of a navigator's bridge on each side of pilot-houses would enable the pilot to see the whole side of his boat and thus prevent many accidents, and the use of two officers to land and maneuver a boat would not be necessary. The use of engine-room telegraphs would prevent the misunderstanding and mistakes in bells, and the many occasions of intense overheating of pilots and engineers would not occur, besides the loss of time and money. Steel houses and modern attachments and practice will prevent the many above enumerated losses from preventable accidents, and the properly designed boats would prevent the many losses from delays and elapsed time, all making towards more satisfactory and economical trips of the boats; and the element of safety found in the unburnable and unsinkable boat will go a long way towards inviting many passengers who would not otherwise patronize the boats. Even now many boats carry their capacity as many trippers and way passengers are being carried. What would be the result, should a freight train back out of Memphis and turn around at every station at which it stopped? The general manager of that road would be discharged before the train reached Friar's Point. There is no profit in carrying freight for the same tariff as the railroad and backing it out of port and for many useless miles downstream as we now do. The boat owner pays this great loss of time and money. With fast express steamers properly designed high-class cargoes can be delivered in about half the time now required by the railroads, so that a reduction in the tariff would not be necessary.

The general impression that railroads kill steamboats is untrue, as evidenced by the many passengers carried on the Hudson River on two or three lines of boats and as many railroads; also on Long Island Sound, with its many well-patronized boats, and one outside line, and as many railroad lines to Boston. There are three lines of railroad from New York to Norfolk, and the Old Dominion Line sometimes operates eight ships a week, and always seven. The Chesapeake Bay steamers are in direct opposition to valuable and active railroads, as also are the boats on the Potomac River from Washington to Norfolk. On many of these lines it is impossible to obtain berth room without several days' engagement ahead. A steamship line from New Orleans to Florida ports is prospering, its passenger fares about

paying its running expenses, and there is also ample railroad service with which this line competes. With these popular boat routes, not to mention those on the Great Lakes, why should we sit down in the belief that it is impossible to inaugurate paying and popular service on our western rivers, where there is no maintenance expense of right of way, no upkeep of block system and dispatchers, where we can save 60 per cent of fuel by condensing, whereas locomotives can only save 16 per cent; where we have no dust or cinders, where we can get exercise, good food and interesting landings. Safety in construction, economy in operation and boats adapted to the waters we now have will go a long way towards deeper rivers and overcrowded landings. Freight handling devices at landings and terminals will solve the vexed problem of independent roustabouts, and, as President Stuyvesant Fish of the Illinois Central Railroad once wrote, "Water transportation can carry freight from one-sixth to one-eighth the cost by railroad." We should not depend upon heavy freights carried by barges to rebuild the waning river trade. For, if we install barge lines, we immediately get all of the lower class cargoes that the railroads do not want, whereas, if we place on schedule runs high-class, high-powered, safe and inviting packet boats, we get first-class rates and many passengers, and we will make three trips to every one of the barge line. Should we be able to save the details as above mentioned, which are so readily seen as practicable on other waters, we would have more money left for other expenditures that are not so readily reduced as is the present fuel expense and the great loss of time as above set forth.

DISCUSSION.

The Chairman:—This paper, No. 9, entitled, "Construction and Operation of Western River Steamers," is now before you for discussion. It has rather to do with the operation of steamers than their design and construction, but there seem to be some matters of interest in the paper, and as we have some expert steamboat men here, perhaps some of them would care to comment on it.

As there is no discussion on the paper, we will pass to the next paper. I ought to say, in passing, that Paper No. 5, on the "Stability of Lifeboats," has been postponed until to-morrow, with the consent of the author, to suit the convenience of certain people who desire to discuss the paper, and Paper No. 8, on the "Evolution of the Lightship," has also been postponed until to-morrow as a matter of courtesy to the Chief of the Lighthouse Service, Mr. Putnam, who could not come to-day but will be here to-morrow. The author, who is in the office of the Lighthouse Service, requested as a matter of courtesy to his chief that the reading of the paper might be postponed until to-morrow morning.

As the time is yet early, we will take some of the papers which were put on the program for to-morrow. The first one will be No. 10, entitled, "The Influence of National Policies on Ships' Design," by Capt. W. L. Rodgers. In the absence of Captain Rodgers, Mr. R. H. Robinson has kindly consented to read this paper.

THE INFLUENCE OF NATIONAL POLICIES ON SHIPS' DESIGN.

By Captain W. L. Rodgers, U. S. Navy.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

It is not unusual for people to assume that a carefully designed, well-built man-of-war is a stock article, as good for one navy looking for ships as for another.

This not only is not true, but it has never been true at any period. If we go to our histories we shall see a constant progress and development in the types of men-of-war, and that different nations at the same date have had navies composed of ships of types which they have inherited from their past political and their geographic affiliations.

As an early example we may refer to the campaign of Actium in 31 B. C., between the levantine fleet of Antony and Cleopatra and the Roman fleet of Octavius Cæsar. The civil wars of the previous half century had permitted the development in the central and western Mediterranean of great numbers of pirates who interfered with Roman commerce. About ten years before Actium, Octavius established a strong fleet to put down the pirates and ensure the Roman commerce. This fleet he placed under the command of a very great Admiral, Marcus Vipsanius Agrippa, who was also a great naval administrator. For the police of the seas, which was the pressing political need of the day, Agrippa developed a new type (of men-of-war) known as liburnæ, specially designed for the pursuit of small groups of piratical craft. These vessels were swift and lightly built; their crews fought with slings, javelins and bows and arrows. In a few years with these ships designed for the purpose, Agrippa suppressed piracy. When the strife between Octavius and Antony broke out, it was with the fleet designed for the police of the seas that Agrippa had to encounter a real battle fleet.

On the other hand, the levantine fleet was composed of the contingent squadrons of the vassal kingdoms acknowledging Antony's supremacy. These contingent squadrons were the fruit of over three centuries of development of the invention of mechanical artillery. They represented the efforts of wealthy and organized governments to maintain rival great fleets for the furtherance of strictly political objectives.

Previous to the invention of mechanical artillery in the early part of the fourth century B. C., the chief naval weapon was the ram, and ships were swift and light to maneuver to advantage. The rowers could spurt them to about 7 miles an hour. But the addition of the mechanical artillery to their weapons led to gradual in-

crease in size and weight, and as the motive force depended on the number of rowers who could be placed along the side of the ships, the speed and handiness fell off proportionately. Besides, the scantlings were increased to stand the impact of heavy projectiles (two to three hundredweight).

Thus at Actium the opposing fleets were of totally distinct types of ships; one with heavy artillery, with stout sides, and consequently slow and unhandy, yet possessing as a survival those rams which had been the dominant weapon of three hundred years before; the other with swift, light ships, without rams, depending on hand missiles. The result of the battle was favorable to the Roman fleet of light ships. Rome became the sole political power on the shores of the Mediterranean. The disappearance of rivals reduced the Roman navy to a police force and caused artillery to disappear from the seas until gunpowder brought it back in a modified form over a thousand years later.

The Roman fleet at Actium was the outcome of political conditions which the fleet itself had ended. That it was successful was owing to the marvelous tactical skill of Agrippa, who had the supreme art to fuse the use of the newest warlike inventions so thoroughly into his scheme of tactics that they were an integral part of the victory. There is a touch of modernity about Agrippa's whole conduct. On the levantine side, the vassal powers of Antony were rich and unprogressive, and their fleets, too, were the product of past international relations, but they did not have the good fortune to be led by a man who could adapt his poor tools to the conditions confronting him.

Passing on for 1,600 years to the campaign of the Spanish Armada in 1588 we shall see the same control of ship design by national policies.

On the Spanish side, that nation for centuries had been closely related to Italy and to Mediterranean affairs. Her fleet had developed with a view to maintaining her position there; it had formed a contingent of the Christian forces at Lepanto only seventeen years before, and the men who had distinguished themselves at Lepanto were now in command in the English campaign.

The Mediterranean policy of Spain had given her a fleet suited to Mediterranean waters. It consisted of galleys, long, rowing craft, poor sea boats, built chiefly to use the ram and to board the enemy, but equipped with artillery as an auxiliary weapon. Spain also had another and more recent national policy; namely, the exploitation and development of her American discoveries and conquests. The annexation of Portugal only four years before had added greatly to these transatlantic provinces, as well as to the fleets of Spain. The over-sea navy of Spain was of quite another type from her Mediterranean navy. It was composed of galleons, a type of sailing ship having great beam for its length, fitted for cargo carrying, and armed more for protection against pirates than for use in the line of battle.

The Spanish nation was rich, self-satisfied and conservative. Neither the Mediterranean fleet nor the ocean fleet was advancing in material. The leaders were content to believe that the tactics which had brought success against the Turks would do so against the English. Accordingly, when the rising commerce of

England began to compete with that of Spain and the attacks of Drake and other great English seamen had driven Spain beyond endurance, it was with the somewhat unsuitable types of Portuguese ships, reinforced by a few of the largest and finest of the Mediterranean galleys, totally unsuited to an ocean campaign, that Spain set out for the English Channel.

On the opposing side all was different. England was just beginning to rise in maritime commerce. Everything was progressive, for she felt the need of struggling to force herself into "a place in the sun." Unlike Spain, she had only one field of effort, the ocean; her ships were designed to overcome the Spanish ships; they were faster, new inventions permitted them to sail closer to the wind, and they carried their heavy long-range batteries on the broadside.

The English leaders were prepared to use their ships to the best advantage. They had fought the Spanish before and they knew that the latter were resting on their past achievements, seeking no improvement.

At last the Spanish fleet appeared in the Channel with ships of two different types originally designed to support the two national policies of Spain, with leaders wedded to the ram tactics of the smooth Mediterranean, and the fleet in line, in the ramming formation. The English met the attack with a homogeneous fleet of a type suited to the English policy, in waters to which the English fleet was adapted. The English tactical formation was column suitable for developing the superiority of the batteries at long range. The victory fell to the side which deserved it through the singleness of purpose reflected both in the design of the ships and in the tactics of the admirals.

Again we must notice how the design of the ships is the issue of respective national policies. The national spirit led Spain to unprogressiveness, and England to every improvement in material, whose use the leaders thoroughly incorporated in their tactical schemes. A far-sighted policy supported the genius of England's admirals.

Passing over another three centuries we come to our own Civil War. The outbreak occurred at the period of transition from sails to steam as motive power, and when iron was beginning to replace wood in the construction of vessels. The United States had few ships of any sort. The Federal Government at once embraced the national policy of throttling the commercial life of the Confederacy by a maritime blockade while armies occupied the insurgent territory. Every sort of ship was seized upon to execute this policy, but a chief part fell to the monitors. In these ships Ericsson's invention of the revolving gun turret was mounted on a ship design suitable to the blockade of the shallow waters and sandy coasts of the Southern States. The development was entirely suited to its purpose, but the close of the war found the country in possession of a fleet suited to peculiar conditions, the outcome of a pre-existing political situation.

The country at large, and indeed the Navy, took little heed of the special maritime features of the war, and like the Spaniards after Lepanto, concluded that the ships which had given satisfaction once, necessarily would do so again. So the

country settled itself to internal development and to repairing the ravages of the war. No one suggested that the Navy was unprogressive in keeping only the old monitors ready for use. Congress and the Navy Department remained under the influence of officers who had served in the Civil War and whose thought and reflection were limited to that war. Accordingly, when the Spanish war broke out, although it opened new policies and new theaters of action to the country, the effect of these was not understood, and that very summer of the war Congress authorized the last monitors obsolete before they were commenced.

But fortunately the country already had started on the proper plan of designing ships to suit the national policy, although it was done with hesitation and false steps which are not without interest to us in this study.

As the wooden ships of the Civil War became worn out, the Congress authorized in 1882 the adoption of steel vessels; the first of these were small cruisers whose purpose was chiefly to continue the police work of the navy in time of peace, particularly in countries with unstable governments. The designing and building of these ships served to educate our naval architects and shipyards in steel construction. Indeed the plans of several of the earlier ones were purchased abroad and in others we imitated foreign models without any thought that designs suitable to another country's necessities did not perforce suit ours.

One of the most instructive of these misfit designs was that of the New York, to understand which we must go far afield and begin with a consideration of the international relations of France and Great Britain in the eighties of the last century.

At this time the relations of those powers were not as cordial as they now are; Germany had not come to the front as the commercial and naval rival of Great Britain so prominently as at present. The fleet of France easily led those of the other countries of the Continent of Europe, and was second only to that of England. The two navies looked at each other as probable and formidable adversaries.

While the French navy recognized its inferiority to the British in combatant strength, its strategic studies led it to believe that it might very seriously embarrass and even distress Great Britain by intercepting the latter's seaborne commerce.

With this purpose in view the French Government of the day laid down a number of commerce destroyers of the type of the Tage and Cecille; swift ships lightly armed, to act from French ports against the hostile shipping in the neighborhood of the British Isles.

The British replied a year or two later with the Blake and Blenheim, somewhat larger, faster and more heavily armed and protected to act as commerce protectors—to chase the French commerce destroyers from the seas.

Here on both sides we have national policy legitimately controlling ship design.

The American Congress at this time was desirous in a general way of building up the navy, but the Navy Department had no idea of co-ordinating the building program with the national policy which was then as now "America for the Americans." This policy called for a fleet capable of maintaining the control of

American seas against possible transatlantic enemies. Consequently, the Department, in selecting a design on which to spend the appropriation of the year, considered that the Blenheim type was about the best that it could see for the Navy and proceeded to attempt to improve on it. The result was the New York, a very fine ship from the shipbuilder's point of view, but a misfit from the national point of view, because she was a commerce protector. The United States had no ocean commerce to be protected. The New York was a very superior British craft, but a poor American one. A year or two later, the Navy Department in its search for ship design, and apparently with the wish to have every sort of tool in its kit, produced two ships of the French type, the Columbia and Minneapolis. As in the case of the New York, there were no ships of the type superior to these "Pirates," as they were called, yet they also were misfits for America. Owing to America's lack of coaling stations and general inferiority in naval power there was no probability that these ships could accomplish anything serious against hostile commerce.

But at this same time the report of the so-called "Endicott Board" on coast defense, made in 1886 and based on a full consideration of national requirements, had borne fruit. The first of our present battleship fleet was already begun. In these ships national policies controlled the design and we have continued to develop this type.

It may be interesting to show the method which the Navy Department now follows in order to check aberrations of ship design which may result in excellent specimens of naval architecture unsuited to the needs of the country. All the great powers take steps with the same purpose of controlling naval design to suit policy.

The close of the Spanish war showed that the organization of the Navy Department was very incomplete in that it was not based upon the requirements of war, but upon those of the routine of peace, and further, the various branches of the Department were semi-independent and did not co-ordinate with each other as they should even for the daily demands of administration in times of peace. Moreover, the existing branches of the Navy Department were wholly absorbed in their own administrative duties, and so were unable to take a wide outlook upon naval affairs in general and their relation to the country at large.

As a partial remedy for this condition the Secretary of the Navy established a board of officers of high rank sitting permanently in Washington which was named the "General Board," whose duties were to be entirely non-administrative, but which were to study, deliberate and report upon all large questions of naval policy as derived from national policy, so that this board could indicate the general direction of naval effort, leaving all details of execution to the administrative bureaus responsible therefor.

Among other duties assigned to the Board by the Navy Regulations is that of studying the naval policies of other countries for comparison with our own and recommending numbers and types of ships which the Navy needs in order to be able to maintain our national policies in the face of opposition. A further duty of the Board is to study and report upon the military characteristics desirable in the various types of ships it recommends.

By military characteristics is meant the broad features of offensive and defensive strength, speed, radius of action, etc., etc. The technical means taken in the construction of the ship to assure these military characteristics are beyond the purview of the General Board. Thus the General Board would recommend the proper speed for a scout cruiser, but it would not consider at any stage of the design whether the proposed horse-power was sufficient to obtain that speed.

Nevertheless, when the General Board considers a new type of ship and the military characteristics which it should possess, the Board keeps itself in communication with the constructive bureaus so that its recommendations shall not outrun practical possibilities of the day.

In this way, the shipbuilding program of the Navy for the last few years has had a unity and a consistency from year to year which was previously lacking because no agency existed in the Navy Department for directing the skill of the technical bureaus to meet the particular strategic and tactical requirements which the national policies are likely to thrust upon the Navy in time of war.

Turning towards other nations, we shall find that they all take means to cause ship designs to harmonize with the national policy.

Taking Germany as an example, it is apparent that the last forty years have been marked by a great development of manufactures and of foreign commerce, and the country has felt the increasing necessity of obtaining foreign markets.

Coincident with the development of these commercial projects has been the rise of the German navy. The Emperor embodied the national belief in his phrase "Our future lies on the water."

If now we compare year by year the ships of the German navy with contemporary ones of other powers, we shall be struck with the gradual modification of German types relatively to those of other powers to accord with the increasing field of German commerce and the increase of the relative strength of the German navy as it thrusts itself to the front in the race for naval supremacy. This change in the relation of the German national type to others is expressed in the increase in the calibers of guns and still more in the increasing fuel endurance of German ships. From a small navy for local defense it has been forced to become a great navy of offense, to extend and protect German commerce and German markets. The regularity of this development of general type and the harmony always existing between the characteristics of different contemporary types show the controlling influence in Germany of national policies upon naval ship design.

The conclusion seems manifest that just as in the business world the managing shipowner prescribes to the naval architect the qualities which his ship must possess in order to fulfil the conditions of the trade, so in navies, the products of the naval architect's draughting room must be in accord with the views of accredited expositors of national policies. These expositors of national policies must communicate to those responsible for the design and development of armies and navies the trend of policies in order that national armed forces may ever be suitable and adequate supports of national policies.

But in our country to-day the bond and intercourse between the statesmen who guide our national policies and the War and Navy Departments which may be called upon to enforce those policies are neither as close as they are in other great powers nor as they should be with us.

DISCUSSION.

Mr. R. H. Robinson, *Member of Council:*—I happened to be for eight years at one end of the line that has to do with designing and building ships for the Navy at Washington, and while my view is, perhaps, somewhat warped, I was not blind. Captain Rodgers refers to the fact that our lack of ability resulted in the production of unsuitable types of ships. I think there is something in what he says, but I do not think it is any more true of our service than of any other service during the period of which he spoke. Somebody referred to the French navy as a collection of naval samples, so I suppose the same criticism as made here must have been applicable to that service.

Captain Rodgers refers to Germany as apparently an example which should have been followed. I have never been of the opinion that we knew it all, or that we could not learn anything from Germany, but my experience in the Navy Department and at the War College, where Captain Rodgers was President, led me to believe that Germany was largely held up as an example because it was probably the nation about which we knew the least. Their results are very good, but just why they do things we do not know. They are very reticent about their reasons, and therefore they are supposed to have very excellent reasons.

The General Board is referred to as having a further duty, namely, to study and report on the military characteristics desirable in the various types of ships which it recommends, following which is a definition of military characteristics. I think I am correct in saying that at least three times while I was in the service I wrote and asked what a military characteristic was, and never had any definition before, but have it here. I remember several instances when the military characteristics were prescribed in the design of ships while I was in the Navy Department, one of which stated that the vessel should be fitted with a No. 8 jeweler's lathe, which did not seem to me to be a very broad feature.

It is quite the custom for the General Board to dictate the type of armor design, the shape of the back of the armor plate, and the shape of the bow of ship, particularly under water, etc.—it was very seldom made the way they dictated, but these features were almost always included in the military characteristics. Such features as the vertical echelon arrangement of turrets, and other things which are really based on military considerations, were developed in the technical side of the department. I dare say that Mr. Linnard, Mr. Taylor, and possibly the Chief Constructor and Admiral Bowles, probably remember many other instances, both on one side or the other.

I do not want to be considered as objecting to the general principles as formulated in the paper, because I think they are very sound, but the manner in which they are sometimes carried out is not quite according to what might be considered good practice.

Mr. Francis T. Bowles, *Past President*:—This paper, I think, ought to be a gratification to the members of this Society. I can recall times when officers in the line of the Navy have been heard to complain of the methods of design, etc., that they were not what they ought to be, and criticize the views of naval architects and marine engineers.

This paper informs us, to our gratification, that the Navy Department has now a method of producing the designs of vessels which are suitable, and that the vessels produced are creditable, and I am very much pleased to hear it. No doubt the members of the Society are gratified.

The Chairman:—Obviously this is a subject on which those who have been and are still keeping in close touch with the matter are the ones most naturally pointed out to discuss the paper. It may be that some others here, although not feeling themselves in this category, have, nevertheless, taken it up as a subject in which they are interested, and they might have something to say.

Apparently we shall have to trust, for a reply to the discussion, to having the stenographic report sent to the author, and he will make such comments as he wishes.

Captain W. L. Rodgers (Communicated):—Mr. Robinson remarks that I referred "To the fact that our" (naval constructors) "lack of ability resulted in the production of unsuitable types of ships." I did not mean to reflect upon the technical ability of the constructors of the Navy, for from the beginning of the American Navy it has at every period built ships which have commanded admiration for the technical skill of their design. The Navy has always had able designers.

As I have tried to show in my paper, the broad features of design must suit the particular requirements of national policy and geography, and this requirement has not always been met. The tool must fit the hand of the workman. It is therefore necessary for those who are going to use naval ships to lay down the qualities to be embodied in them. The technical means employed to secure these qualities belong to the sphere of the naval architect.

The seaman and the architect must co-operate to produce suitable types of ships, and each has his own responsibility in the product. If either architect or seaman outsteps his own limits, he may perhaps be wise and correct in his views, but in offering them he does so as an amateur and not as an authority.

The Chairman:—The next paper is No. 13, entitled, "General Consideration of Navy Yard Design, Location, Capacity and Maintenance, with Plan and Description of a Large, Efficient Yard Properly Located," by Captain L. S. Van Duzer, U. S. Navy. In the absence of Captain Van Duzer, the paper will be read by the Secretary.

The Secretary presented the paper.

GENERAL CONSIDERATION OF NAVY YARD DESIGN, LOCATION, CAPACITY AND MAINTENANCE, WITH PLAN AND DESCRIPTION OF A LARGE, EFFICIENT YARD PROPERLY LOCATED.

By Captain L. S. Van Duzer, U. S. Navy, Associate.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

During the past five years our navy yards have been given more than usual attention. This attention has been chiefly directed towards organization, management and the suppression of unimportant yards and stations.

The uselessness and expense of these subsidiary yards have always been well known, but local politics have prevented their abandonment. Recently strategic reasons have added force to the economic ones and we now see that we must have at least one great yard where the entire fleet can be repaired and supplied in time of war. It cannot, in a war with a powerful nation, be divided. Therefore, at least one properly located navy yard must be adequate to quickly effect repairs and docking, and furnish supplies.

Having determined that we need one great yard, it is necessary, before beginning its construction, to investigate the requirements and desirable features. These may be divided into:

I. Suitability of location.
II. Capacity.
III. Cost of construction, maintenance and operation.

I. SUITABILITY OF LOCATION.

This comprehends:—

(1) Strategical position as regards the probable operations and requirements of the fleet.

(2) Strategical position as regards defense.

(3) Accessibility under all conditions of tide, wind, and temperature. This involves:

(a) Depth of water and safety of approach.

(b) Proximity to main channels and ease of approach.

(4) Accessibility and proximity to the great highways of transportation.

(5) Proximity to a great center of supply of materials.

(6) Proximity to a great center of supply of labor.

(7) Proximity to a very large city where liberty can be given to a large number of men while the ships are under repair at the yard.

II. CAPACITY.

This includes:—

(8) Capacity to keep the fleet in repair in time of war.

(9) Capacity to keep the fleet in repair in time of peace.

(10) Capacity to keep the fleet supplied in time of war.

(11) Capacity to keep the fleet supplied in time of peace.

(12) Capacity to build ships of the largest size.

(13) Capacity to quickly repair ships under all conditions of injury and draught.

(14) Capacity to berth, repair, and supply at one time a very large number of ships of the largest size.

III. COST OF CONSTRUCTION, MAINTENANCE AND OPERATION.

This includes:—

(15) Cost of yard and plant.

(16) Cost of maintenance.

(17) Cost of operation, which involves:

(a) Efficiency of operation as regards speed of doing work under varying conditions of weather and volume of work.

(b) Efficiency of operation as regards cost of doing work under varying conditions of weather and volume of work.

I. SUITABILITY OF LOCATION.

Taking the various requirements in succession, we find with respect to (1), that the position of New York is superior to all ports on the coast as regards depth of water and ordinary ease of exit and entrance, with the single exception of Narragansett Bay. It is the only port on our whole coast which has two entrances separated by 100 miles. It is nearly in the industrial center of the coast. It is somewhat farther from Europe than Narragansett Bay, but the difference is so small as to be immaterial, while it is a little nearer to the Panama Canal.

As regards (2), it is easy of defense against sea attack, as compared with Narragansett Bay, and, furthermore, New York is always likely to be incomparably the best defended port on the coast, its great interests and the character of its entrance both contributing to this end. A navy yard located at the place indicated in the accompanying drawing is a mile or two farther away from possible sea attack than the present yard. And it is far more secure against a landing force than any location on Long Island, or almost any other practicable location in New York harbor, or elsewhere. As against a naval raid, its security is practically absolute, while any conceivable location in Narragansett Bay is peculiarly open to this form of attack.

As regards (3) the accessibility under all conditions of tide, wind, and temperature, the low-water depth in the entrance channels of New York has, for fifty

years, been maintained at 10 feet greater than the deep-load draught of the heaviest battleships. This condition, based upon the draught of heavy freight vessels, is practically certain to be maintained. The margin of depth (to which tidal rise adds 4 or 5 feet) is sufficient to take care of any probable draught of a battleship due to injury. The depth at all points from the entrance channels to far above the suggested location of the yard is considerably greater than in the channels. The only dredging necessary would be in and near the yard wharves and piers. The suggested location of the yard and the arrangement of piers is such as to render access particularly easy. The currents in this locality are very much less than above or below, owing to the width of the bay in this vicinity and to the configuration of the shore. This part of the harbor is also quite free of drifting ice, which gives much trouble in both the East and North Rivers. In foggy weather New York harbor is much easier and safer to enter than Narragansett Bay. The slowly shoaling water gives to a careful navigator definite and ample warning of the approach to danger; and that danger is a simple grounding on sand and not striking rocks. Moreover, New York fogs are less frequent and generally less dense and of shorter duration than those of Narragansett Bay. In this connection, it must not be forgotten that a navy yard site in Narragansett Bay is far above Newport and involves a long and rather tortuous passage between rocky shoals and islands.

As regards (4), the west end of a yard (of the type hereinafter suggested) located below Communipaw would be close to railway tracks leading to all the great trunk lines of the country, while the water front would be accessible to every form of vessel or barge and only shortly distant from the wharves of all the steamer lines, coastwise and foreign. A navy yard located in Narragansett Bay would be dependent upon service from only one railway and that railway's steamers. Such a condition of affairs would be well-nigh intolerable, aside from the added expense of freight.

As regards (5) "proximity to a great center of supply of materials," New York is incomparably superior to all other ports, as it is by far the greatest center of supply of materials that exists on the western continent. Articles of ordinary commercial design and composition can be obtained in a few hours. In Narragansett Bay, supplies would ordinarily take several days for delivery and could not be selected except at great cost. Nearly all would come from or through New York. The supplies of provisions and of coal and oil fuel are at hand in New York, and from dozens of sources. The great coal roads would lead directly to the yard, while the main oil pipe lines end only two or three miles away and oil could be piped directly into the yard. No such conditions exist in Narragansett Bay. The stock of all supplies in such an isolated location would have to be enormous or the delays would greatly hamper work and add materially to the cost of it.

Concerning (6) the conditions of labor supply in yards, which are not near large cities, is well appreciated by all who have had experience in them; the labor situation in a large yard located in Narragansett Bay would be serious. Only work-

men continuously employed would be available. Men will not go far for employment lasting only a few days or even weeks. Sudden and temporary increase of force in an emergency would be impossible. Greatly increased wages might bring mechanics after considerable delay and much trouble; but labor offices would have to be opened and maintained in New York and Boston. Labor difficulty alone should preclude us from attempting to place a yard on which the fleet (or even a portion of it) depends for repairs and maintenance at any great distance from a source of supply of labor of all kinds and in any quantity.

As regards the liberty of the enlisted force, the desirability of having a navy yard adjacent to a large city is of the utmost importance if we are to keep them contented, unless we waste time by giving liberty in one place and at one time and sacrifice a further length of time for repairs at some other point. Such an arrangement is wasteful of the time of both officers and men, and cuts down the time available for drill and training and extends the interval of inefficiency. No other place compares with New York for the purpose of liberty-giving, and a navy yard should exist there large enough to berth the whole fleet. An attempt to keep battleships at anchor in the North River and similar places in winter invariably results in the drowning of members of the crews and loss of steam launches and other boats.

II. CAPACITY.

As already stated, it seems perfectly clear that one navy yard should, if possible, be large enough to quickly repair the whole organized fleet in time of war. The separation of the fleet into three or four parts for any reason whatsoever is strategically wrong. No vessels should be separated from the main body of the fleet except such as are so badly injured that they will be out of service for many weeks or months. The strategy points to the establishment of the largest kind of a yard in the best possible location with the best possible defenses.

The great central yard should be large enough to keep the whole active fleet in repairs during peace as well as war. A large establishment is much more efficient and economical than several small ones. If the smaller yards serve no useful purpose in war they are equally inefficient in time of peace and should no longer be maintained.

As regards (10) and (11) (the capacity for supplies in time of peace and war), it is perfectly apparent that if we put a navy yard in a place like Narragansett Bay we must run the risk of failing to provide supplies at a critical moment or have enormous storehouses in the navy yard. In the latter case the losses from deterioration of stores will be very considerable. A navy yard located in New York harbor need have comparatively small storage capacity, for the warehouses and storehouses of the whole city are so close as to render them an annex to the yard.

The capacity to build ships of the largest size is a necessary feature of a great navy yard, and is not a very expensive addition to a great repair plant unless the considerable area of ground necessary is costly owing to high value of land.

The capacity to berth, repair and supply the whole fleet at one time and to repair the largest ships rapidly under all conditions of injury and draught implies large and well-equipped shops, ample wharfage capacity and numerous large dry-docks. It also implies very deep water in the approach to the dry-docks, and at least one dock with great depth over the sill. And the storage, transportation and similar facilities should correspond to the other equipment.

III. COST OF CONSTRUCTION, MAINTENANCE AND OPERATION.

The cost of the yard and plant should be as low as consistent with economy and the achievement of the end in view—the care and upkeep of the fleet.

The design of the yard should be such that its maintenance should cost as little as practicable. The power plant should be located in a favorable position as regards fuel and water supply, and be fitted with equipment of the best types, so that the power charges should be as low as practicable, while the character of the buildings and transportation facilities should render upkeep and transportation charges equally low.

Given a well-designed, well-equipped, and well-located yard, the efficiency of operation as regards both cost and speed depends upon suitable organization and methods of carrying on work.

THE NEW YARD PLANNED.

The accompanying sketch, Plate 48, shows only the main features of the design. Some details cannot be shown except on a larger scale, and they are so numerous that many of them would require additional study. General characteristics shown are planned to meet the requirements enumerated in the foregoing pages, and are independent of the exact design of details.

Location.—It will be noted that the proposed yard is placed where its inner end abuts land contiguous to all the great railways, and that its outer end reaches deep water. The cost of supplies of all kinds is therefore reduced to a minimum. The yard is located where the tidal current is always weak so that it is easy of access. Access is further facilitated by placing piers at 45 degrees with the direction of entrance and with the direction of the tidal current. The location of the yard is such as to render it quite free from ice accumulation during winter, except such as may form in and around its own piers.

Wharves, Piers and Docks.—There are twenty main piers, all of 700 feet length. These twenty piers will berth forty battleships or other war vessels of the largest size. At the wharves between the piers there is berthing space for eighteen ships of length of 425 feet or less. Three other large vessels can berth at the outer end of the yard. Twenty torpedo vessels or small craft can berth at the outer ends of the piers, while about 100 tugs, barges, submarines, etc., can be berthed at the piers (with the battleships, which are all less than 600 feet long), or elsewhere about the yard. Its shape has been carefully studied and the one chosen

is believed to be the best for wharfage space, convenience of operation and general efficiency. The placing of the dry-docks at the outer end prevents their interfering with the yard transportation. Additional docks can and should be added if this yard is to take care of the whole fleet. The docks shown in the plan may be entered at either end and each has a middle caisson which has several seats so that the dock may be divided into two single docks of variable length.

The Building Ways offer nothing particularly new. The estimates given are for the utilization of the old ways (those in the present yard) as far as possible. If not too expensive a double gantry crane instead of the present cantilever might be desirable. The plate yards are covered with railway tracks on a system that should cheapen the handling of material.

The Outer Row of Shops.—The shops of the outer row on each side of the yard are of one story only and are 120 feet wide exclusive of any slight additions to the floor space made by the lean-tos such as would be desirable in foundries. All shops are reached by standard gauge railway tracks (single dot and dash line); while the shops where heavy weights are handled are reached by the sixty-ton-crane track (double broken line). The positions of the tracks are only approximate and further study on a larger scale might change a number; some additions should doubtless be made. All curves are of 125 feet radius.

The Inner Rows of Shops.—These shops are on the lower floors of two-story buildings. They are eighty feet wide and are all reached by standard gauge railways.

The Storehouses.—The second floor of all the inner rows of shop buildings forms the general storehouse for all active stores, except those of very great weight or those which are supplied only to ships and are not used in any process of yard work. The ends of these buildings are connected by covered bridges and at the east and west ends a covered structure supports and covers a track connecting the north row of storehouses with the south row. This gives a continuous track. On this track it is intended to run trolley trains (always in one direction) for distributing stores and transportation of people—particularly of foremen and leading men who are inspecting stores desired for use, and of men sent to the storehouse for certain articles urgently needed. It will be noted that this continuous railway track (with two full-length sidings in each building) will reduce enormously the cost of handling, the time of delivery, and the convenience of examination. When desirable to do so, railway cars would be hoisted on the elevators in the receiving store or lumber store and run to the place where their contents would be stored. Stores for the inner row of shops are lowered through small elevators directly to the spot desired. Stores from the outer shops are lowered on cars which can be brought alongside or inside the outer shops.

The Buildings of the Central Row are only 60 feet wide. On the ground floor there are miscellaneous storerooms, the electrical school, yard restaurant, etc. On the second floor are all the yard offices, the Commandant and central correspondence and planning office in the approximate center, the other offices grouped around

these. The draughting rooms and certain office storerooms are on the third floor. The office buildings, as the central row may be styled, are the only ones which are three-story, and so far as can be foreseen only part of them need be of that height.

Miscellaneous Buildings.—The provision and clothing storehouse is located outside of the shop area and is for the supply of ships and not of shops. The clothing factory is near it. The paint and oil storehouse is placed at some distance from the other stores on account of the inflammable character of the stores. The paint factory is equally isolated. The barracks and quarters of officers are not shown. They are easily arranged.

The Power House is placed close to the water front so that fuel can be delivered directly into the bunkers of the boiler plant, while ashes can be ejected into the dump scows. It is planned to use oil, but the placing of the power house is such as to render the use of coal as economical as possible, if such use should ever become necessary. The cost of power with oil fuel ought to be less than 0.4 cents per kilowatt hour, this cost to include all expense except plant and to cover repairs and maintenance of plant and distributing systems.

35. The estimates of cost of the yard are as follows:—

Buildings:		
Outer rows of shops, 1 story		
4,400 ft. × 120 ft. = 528,000 sq. ft. at $3.50 =	$1,848,000	
Inner rows of shops, 2 story		
5,600 ft. × 80 ft. = 448,000 sq. ft. at $5.00 =	2,240,000	
Office buildings, etc., 2 and 3 stories.		
2,000 ft. × 60 ft. = 120,000 sq. ft. at $6.00 =	720,000	
Miscellaneous buildings	890,000	
		$5,698,000
Seawall:		
About 15,000 ft. at $175 per ft.....		2,625,000
Piers:		
20 piers 700 ft. × 70 ft. = 980,000 sq. ft. at $2.00 =	$1,960,000	
Miscellaneous piers, 75,000 sq. ft. at $2.00 =	150,000	
		2,110,000
Dredging:		
7,200 ft. × 2 × 1,500 × 27 =	21,600,000 cu. yds.	
500 ft. × 1,200 × 27 =	600,000 cu. yds.	
	22,200,000 cu. yds.	
Less 700 × 70 × 20 × 27 =	980,000 cu. yds.	
	21,220,000 cu. yds. at 15c....	3,183,000
Foreshore and approach.....		1,250,000

Dredging—Continued:

Dry-docks, 2,400 feet at $3,000 per running foot	$7,200,000
Installations and extra equipment	2,500,000
Railways, 16 miles at $15,000 per mile (exclusive of tracks on piers)	240,000
Crane tracks, 4 miles at $60,000 per mile (exclusive of tracks on piers)	240,000
Water, heating, sewers, electric mains, air mains, paving, telephones, etc	1,000,000
Miscellaneous, including some possible additional dredging and unforeseen contingencies	475,000
Total	$26,521,000

If the present yard were sold, the receipts for its sale would go a long way towards paying for the new yard. It may be mentioned here that the proposed yard is not only four or five times greater than the present one as regards berthing capacity and capacity for work, but that it is also two or three times as great in shop capacity and storage space. The dock capacity for very large ships is four times that of the present yard. But it is not enough to take care of the whole fleet and two additional docks should be added if this yard is to attain its true end.

It will be noted from the foregoing that the suggested yard at New York is far superior to any yard in Narragansett Bay. But this is not saying half enough. The Narragansett yard of equal capacity would cost much more to build and equip, much more to maintain, and the work done in it would cost nearly twice as much, particularly urgent and emergency work. Power would cost double and wages very much more. Transportation to the yard would cost very much more; and its insufficient and inadequate character would add greatly to costs through delays and stoppages of work, as well as through high freights due to lack of competition. Adequate fortification does not now exist in Narragansett Bay. To efficiently protect so vital a point as our greatest navy yard is a most important step toward securing victory in war. Adequate fortifications and other defenses for Narragansett Bay would be very expensive and are not needed except for the defense of the yard. At New York, other considerations will always insure ample defense. Nothing need be added because of the yard.

The existing conditions as regards our navy yards have been brought about by the changes in ships and in naval warfare. All the principal yards, except those at Puget Sound and League Island, were located and partly laid out before the advent of steam, when our ships were few and small. Even the largest of them are entirely inadequate; all of them are inefficiently laid out, and with the exception of League Island, badly located.

And the conditions are rapidly becoming worse. The increasing size of the new ships precludes their going to Boston because of the lack of piers of sufficient length.

The New York yard can berth only four 600-foot ships. League Island can be arranged to berth eight or ten of this size, but the yard is too far from the sea to serve as a base for the active fleet. Norfolk is not so well off as New York as regards berthing space. An injured ship drawing more than her ordinary seagoing draught could not be brought to any one of our yards except perhaps Portsmouth, New Hampshire, where the strong currents would make handling of such a vessel difficult.

The reasons for abandoning the existing yard at New York and moving to a new location in the harbor are numerous. The present yard is not only undesirable as regards capacity and accessibility, but it is incapable of satisfactory improvement at any cost. The shape of the waterfront is exactly the reverse of what it should be. The yard surrounds the waterfront instead of the waterfront surrounding the yard. Owing to the strength of the current and lack of depth in East River, not more than three large ships can be brought to the yard or leave it in one day. Greater depth of water would not much increase this number, as very large ships cannot safely be brought into the yard during the strength of the tidal current. As regards berthing space, there is room for but one more long pier. This, if built, raises the number of 600-foot berths to six. The layout of the yard, as regards docks, piers, wharves, shops, storehouses, power plant, and streets, is wasteful of both time and money. The cars of all railway shipments must be brought to the yard on floats, while the internal transportation is unduly expensive owing to unabatable conditions.

The steady increase in size of our battleships and the demand for a very large and properly located yard is most urgent. And while we need it now, the lack of it five years hence will cause a serious reduction in naval efficiency. We cannot therefore begin work upon it too soon.

DISCUSSION.

The Chairman:—This is a subject which I think a great many others than strictly naval people could discuss with a good knowledge of the subject. As I take it, it really is a question of the most suitable location for a large industrial establishment, adapted especially for turning out naval material, it is true, but at the same time it is like any other large industrial establishment. I hope we may hear a number of good comments on this paper.

Mr. E. A. Stevens, Jr., *Member:*—I think the suggestion of Captain Van Duzer in reregard to location is an excellent one, but it seems to me the sticking point would be to get Congress to appropriate sufficient funds to build the yard in the proposed position. On account of the everlasting politics interfering with naval affairs, and the fight that the Brooklyn repre-

sentatives would make to keep the Navy Yard in Brooklyn, I think such a move would be a hard proposition. Such things, however, should not enter into propositions for the Navy, whether it is a question of the location of a yard, or the building of the ships, or anything else. They should be carried out to the best interests of the country and not for the benefit of any particular locality.

Provided that this location can be dredged, there is absolutely no doubt that it is a much more attractive position than the present Brooklyn Navy Yard. The approach is very much easier and, as Captain Van Duzer says in the paper, it is further from attack at sea; not only that, but it is nearer to Sandy Hook—I have not measured the distance, but I should say it was at least two miles nearer. When it comes to a question of time, there would be a great saving on account of the slow speed with which the battleships are required to navigate in the East River. The layout Captain Van Duzer has put before us evidently shows a good deal of thought and seems to be excellently worked out. The location is infinitely better for the transportation of materials, as at very small expense tracks could be laid connecting the yard with two of the main railroad lines which run to Pittsburgh and other locations where the steel industries are situated. Everything which is destined for the Brooklyn Navy Yard has to be taken out of the cars, put on lighters, and transported over there. This difference in time required to get the material and make repairs on ships would be of great importance in time of war.

The Chairman:—There are a number of industrial managers present, men whose opinions on this thing are worth having. I do not want them to give opinions of great value to the government for nothing, but at the same time, for the sake of the Proceedings of the Society, I would like them to say a word or two.

Mr. Francis T. Bowles, *Past President:*—It has always seemed to me, with regard to the Brooklyn Navy Yard, and all navy yards, that naval officers, as a rule, confuse the functions of a navy yard, and attempt to combine what I call a naval rendezvous with an industrial plant. There is a continual conflict between the interests of a naval rendezvous where men are assembled for distribution, recruited and trained to some extent in the performance of their duties, and where stores are kept for renewing supplies on vessels, and a place where industrial work is performed. If there were no other handicap in the way of the Navy producing battleships and other vessels at a cost equivalent to what can be obtained under contract, the cause that I have mentioned would alone prevent it.

The Navy has a very large investment in the Brooklyn Navy Yard, in the way of drydocks and costly buildings, some of which are very well adapted for the manufacturing purposes for which they are occupied. I venture to say that if all the features of the naval rendezvous were removed the efficiency of the yard for repairs, construction and industrial purposes would be greatly increased.

The Chairman:—Has any one else any comments to make on this paper? If not, we shall pass to the next paper, No. 14, entitled, "Notes on the Performance of the S. S. Tyler," by Mr. E. H. Rigg.

Mr. Rigg presented the paper, and at its conclusion said:

"I should like to add a word as to the backing and maneuvering of the Tyler; these were

both tried out during the loaded trials as well as when light, and found to be perfectly satisfactory.

"Reference should be made here to a paper by Naval Constructor D. W. Taylor, read before this Society in 1911, on the influence of form of ships upon their resistance; this paper indicated generally the results to be expected in this case, but as the experiments were upon models somewhat finer than the Tyler no definite prediction as to power necessary could be obtained therefrom.

"The time which elapsed between bottom painting and trials should be stated in this paper. The bottom was coated with McInnes anti-fouling composition, and the ship launched on the 31st of May, 1913. Between that time and the trials, run on the third of August, she was not dry-docked. She lay in fresh water at Camden, N. J., from the launch until July 26, during which time no appreciable fouling would take place."

NOTES ON THE PERFORMANCE OF THE S. S. TYLER.

By E. H. Rigg, Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

The comparative scarcity of accurate and full accounts of the performances of ships built in the various yards has frequently been deplored in connection with papers read before this and kindred societies. This point came up in connection with the short paper read here by myself last year, and it is more to follow up one point then brought forward that the present paper has been prepared rather than on account of any extraordinary interest or originality attaching to the following remarks and figures.

It is comparatively an infrequent occurrence for trial data of merchant ships to be allowed publicity, and the thanks of the author are due to the Old Dominion Steamship Company, the owners, and to the New York Shipbuilding Company, the builders, not only for permission to record here the results achieved, but also for co-operation in furnishing the information necessary for comparative purposes.

In a paper entitled "Notes on fuel economy as influenced by ship design," read before this Society at the general meetings last year, reference was made to the vessel which forms the subject of the present paper. Certain hopes were indulged in as to her performance as a coal saver, compared with similar vessels; since that time she has been completed for sea, run her trials, and been in service long enough for results to be available, and it is hoped that these will not be without interest to members of the Society.

Reference to page 233 and Plate 95 of our 1912 Transactions will give details of the lines and of the model experiments carried out during the design stage of this vessel. Later it was decided to build the vessel 331 feet long between perpendiculars; whereas a model representing a 308-foot 6-inch ship had been towed. This change introduces a necessity for careful calculation to get the effective horse-power for the longer ship. The curve of effective horse-power herewith has been deduced as follows:—

Both ships were worked up from Taylor's standard series. A percentage difference between the model as towed and the shorter ship calculations was obtained and applied to the longer ship calculations to get the required curve, which, therefore, represents the ship as built.

In laying down the Tyler, middle body was added to obtain the new length; the bilge lines were eased, so that there is, strictly speaking, no parallel middle body. On the floor and sides, however, there is some fifty feet of parallel body, or 15 per

cent, which is the figure for minimum residuary resistance, the easing of the bilge being so slight that the vessel has this amount of parallel body for all intents and purposes.

In the 1912 paper a claim was made for a 3 per cent saving, due to the forward lines; the trials at the Delaware Breakwater amply justify this claim. Recent average practice would require at least 2,000 indicated horse-power for 12¾ knots; 1,750 indicated horse-power, as realized, therefore represents a 12½ per cent saving, all of which, however, is not claimed for the bow lines. It would not be difficult to cite similar cases requiring 2,100 indicated horse-power for this speed.

It is to be regretted that there is no other ship in the Old Dominion fleet that can be compared directly with the Tyler. The Madison is a larger vessel, passenger carrying, and 4 knots faster. These ships compare approximately as follows:—

	Madison	*Tyler*
Length	359 ft. 0 in.	331 ft. 0 in.
Breadth	42 ft. 0 in.	47 ft. 0 in.
Draught	16 ft. 6 in.	16 ft. 6 in.
Displacement	4,500	4,750
Sea speed (knots)	16	12
I. H. P.	4,000	1,500

Both vessels have a single screw. These figures are included more to show the difficulty of comparison than as an actual comparison. From effective horse-power curves from a previous vessel it is, however, possible to arrive at a fair comparison. The type vessel is similar to the S. S. Madison in general form.

Item	*Type*	*Tyler*
Length	350 ft. 0 in.	331 ft. 0 in.
Breadth	42 ft. 0 in.	47 ft. 0 in.
Draught	17 ft. 10 in.	16 ft. 11 in.
Displacement	4,875	4,875
Block coefficient	.65	.65
Speed in knots	13	13
E. H. P.	1,100	1,200
Ratio, beam to draught	2.36	2.78
Speed-length ratio	.695	.715

The Tyler is shorter and wider than the type ship and only requries 100 more horse-power for the same speed at the same displacement. Both these performances are creditable to the designers, but especially so in the case of the shorter and wider vessel. The Tyler is an example of a case where several cooks did not spoil the broth.

Besides the Old Dominion Steamship Company and the builders of the vessel, Naval Constructor D. W. Taylor and the Newport News Shipbuilding Company had a hand in preparing the lines of the vessel.

Turning to the propeller side of the question, the propulsive efficiency at 12¾ knots is seen to be some 63 per cent, which, I think will be admitted, is a good performance.

In warship trials, an accurate curve of effective horse-power is generally available, but only very rarely for merchant ships; this fact renders the Tyler's trials decidedly more interesting.

The propeller data will be found in Table 1; the builders were responsible for its design.

The mean depth of water on the course was some 165 feet; information from shoal water trials shows that this is an ample depth for the draught and the speeds attained; the results are therefore not complicated by shoal water effects. The mean depth on the approaches was about 110 feet and this figure also is reasonably satisfactory. The approaches refer to a length of one mile each side of the range buoys. Minimum suitable depth for this vessel is about 125 feet. The service in which these vessels are engaged is a coastwise one, between New York City and Norfolk, Virginia.

Plates 49, 50 and 51 show clearly the easy entrance and run and the consequent absence of heavy wave-making. These photos are by Mr. Higgins.

Since the vessel has been in service she has made frequent trips at a mean draught of 17 feet, and has made a speed of slightly over 12 knots between the lightships. I hope Mr. Higgins will be able to supplement these figures with later data on her sea performances.

TABLE 1.

Hull and Machinery Data.

Length over all		344 ft. 0 in.
Length between perpendiculars, W. L.		331 ft. 0 in.
Beam, molded		47 ft. 0 in.
Depth, molded		35 ft. 0 in.
Draught, aft, on trial		17 ft. 11 in.
Draught, forward, on trial		15 ft. 11 in.
Draught, mean, on trial		16 ft. 11 in.
Trim by stern		24 in.
Corrected displacement	(long tons)	4,875
Freight earning deadweight	(long tons)	2,350
Block coefficient		.650
Longitudinal coefficient		.682
Wetted surface	(square feet)	20,000

TABLE 1—*Continued.*

Hull and Machinery Data.

Engine, triple expansion.
- Cylinders ..... 19¾ in., 33¼ in., 58 in.
- Stroke ..... 42 in.
- Boilers, S. E. Scotch..... (number) 2
- Heating surface, total..... (square feet) 4,182
- Grate surface, total..... (square feet) 105

Draught, heated forced.
- Working pressure ..... (pounds) 200
- Dimensions .....13 ft. 8 in. diameter, 12 ft. 0 in. long

Propeller, four-bladed, solid, cast steel.
- Diameter .....14 ft. 6 in.
- Pitch .....14 ft. 6 in.
- Projected area .....(square feet) 66.7
- Developed area .....(square feet) 80.0

Gross tonnage 3,928

Net tonnage 2,960

TABLE 2.

Results on Standardization Trials. Delaware Breakwater Course, August 3, 1913. (Weather, clear and warm; calm sea; light westerly breeze; ranges clearly visible.)

Run and direction.	Elapsed time. Minutes.	Seconds.	R.P.M.	I. H. P.	Knots.	Slip %.
1—N	7	10.2	59.15	438	8.368	1.108
2—S	8	12.5	57.53	424	7.310	11.270
	Mean.....		58.34	431	7.839	6.189
3—N	5	33.2	74.35	746	10.804	-1.55
4—S	6	42.3	75.30	850	8.948	16.95
	Mean.....		74.82	798	9.876	7.70
5—N	4	39.8	83.00	1128	12.866	-8.31
6—S	6	14.0	82.95	1118	9.626	18.87
	Mean.....		82.97	1123	11.246	5.28
7—S	4	49.5	92.90	1605	12.435	6.45
8—N	4	59.2	92.80	1602	12.032	9.43
	Mean.....		92.85	1604	12.233	7.94
9—S	4	26.2	95.95	1788	13.524	1.509
10—N	5	17.2	94.75	1682	11.349	16.360
11—S	4	05.2	95.65	1723	14.682	-7.29
12—N	5	35.4	95.90	1806	10.733	21.85
	True mean....		95.38	1750	12.793	6.345

NOTES ON STANDARDIZATION.

1. After run No. 6, the vessel hauled off to await the change of the tide from flood to ebb; 2¾ hours elapsed between end of No. 6 and beginning of No. 7.

2. Runs Nos. 7 and 8 were thrown out in plotting the speed and power curves; it was noticed that the tide had not set down and was still running oblique to the course. It is to be noted that the revolutions and power spots check well, but the speed is evidently not correct; the slip curve also bears this out.

3. Four high-speed runs were made and a mean of means taken; this establishes the top spot beyond question.

4. On run No. 9, the Tyler and the Narragansett passed on the course, one to the west and the other to the east of the buoys; it is probable that each affected the other slightly.

5. On run No. 10 it is to be noted that the steam pressure dropped back and consequently the indicated horse-power fell about 100 below the average for the other three high runs. Full pressure would have made the top speed 12.875 knots.

TABLE 3.

Propulsive Efficiency.

From the above data the efficiency figures are as follows, taking the ratio between total effective and indicated horse powers:—

R. P. M.	*Speed in knots.*	*E. H. P.*	*I. H. P.*	*Efficiency in %.*
60	8	270	460	58.7
67	9	380	625	60.8
74	10	520	820	63.4
81½	11	685	1,060	64.6
89	12	875	1,385	63.2
97½	13	1,190	1,870	63.6

Displacement, draught, etc., will be found in Table 1.

It will be noted that at top speed the propeller shows no signs of breaking down.

DISCUSSION.

THE CHAIRMAN:—I hope this paper by Mr. Rigg, entitled, "Notes on the Performance of the S. S. Tyler," will receive an adequate discussion.

Mr. Howard C. Higgins, *Member*:—I want to add that the data which I will present and send to the Secretary confirm the ship's good performance. The owners of the vessel think she is a fine ship, she does good work, and does it economically; just how economically it is difficult to say, as we have no other ship with which to compare her performance. I am willing to give these figures to the Secretary to appear in the discussion in connection with the paper.

The Chairman:—We will appreciate that very much.

The data referred to by Mr. Higgins are as follows:—

Abstract of Logs for November, 1913, S. S. Tyler.

Leaving.		Speed, statute miles.	R. P. M.	Coal (2,000 lbs.)	Mileage.	Mean draught.	Cargo, tons (2,000 lbs.)	Per cent slip.
Port.	Date.							
S-NY	Nov. 1	12.73	86.76	41	339	16′ 2″	2329	10.9
N-PP	Nov. 4	13.12	86.73	80	328	12′ 0″	825	9.2
S-NY	Nov. 8	13.11	92.06	86	339	14′ 1″	1930	14.7
N-PP	Nov. 11	13.48	87.85	86	328	15′ 0″	1554	6.8
S-NY	Nov. 15	13.76	89.90	84	339	13′ 11″	1875	7.2
N-PP	Nov. 18	13.10	82.30	84	328	15′ 0″	1417	3.4
S-NY	Nov. 22	12.67	83.90	72	339	16′ 10″	2125	8.4
N-PP	Nov. 25	13.21	83.80	72	328	12′ 9″	1093	4.4
S-NY	Nov. 29	13.79	87.30	..	339	13′ 11″	1426	4.1
Totals . . .		118.97	780.60	363	3007	. . . .	14574	69.1
Averages . .		13.22	86.73	40	334	14′ 5″	1619	7.7

Speed, knots per hour	11.48
Coal per trip, tons (2,240 lbs.), including port consumption	35.71
Knots per trip	290
Tons cargo (2,240 lbs.) per trip, including port consumption	1,446
Tons knots per trip, including port consumption	419,340
Pounds coal per trip, including port consumption	80,000
Tons cargo, one knot per one pound coal, including port consumption	5.24
Pounds coal per knot, including port consumption	276
Cubic feet cargo space per ton (2,240 lbs.) cargo carried	198
Tons cargo carried per ton of coal consumed, including port consumption	40.2
Average pounds per mile, no deduction for por use	249.5
Displacement (tons) at 14 feet 5 inches	3,925

Attention is called to the small cargoes carried on several trips and the large average space (198 cubic feet) taken up per ton. This is due to the business being largely a one-

way movement; and the ship being generally dispatched on schedule, regardless of the amount of cargo offering.

Had it been possible to obtain a full load each way, each trip, the performance as shown would have been much improved.

Professor C. H. Peabody, *Member of Council:*—I congratulate Mr. Rigg in presenting us with the trials of a merchant ship under favorable conditions, and I wish also to express my appreciation of the statement he makes that there is no serious difficulty about preparing merchant ships for such tests. I wish he would kindly inform us what methods were used in this case for producing such a load, because it has come to my knowledge that in many cases it is exceedingly difficult to get a merchant ship properly loaded for trial, that in some cases there is no way of loading except by throwing cargo or ballast into the hold, and I believe that both of these performances, while possible, are frequently inconvenient.

Captain C. W. Dyson, U. S. N. (Communicated):—In reading over the article prepared by Mr. Rigg, I note that he makes no reference either to the beneficial effect of the very full midship section on the after body lines nor upon the happy choice of revolutions for the propeller.

While the complete lines of the hull govern the effective horse-power required to tow that particular hull at any given speed, the indicated horse-power necessary to be developed by the propelling engines in order that this effective horse-power may be delivered depends directly upon the form of the after body lines, upon the designed revolutions and the permissible diameter of the propeller.

In designing a propeller to deliver a given effective horse-power, and to realize the maximum tank efficiency possible, a certain diameter and a tip speed corresponding to this diameter are required. In addition, the after body of the hull must be of such form as will permit the water from forward to flow to the screw and to enter it in a solid unbroken stream. This I will designate as Condition 1; it is met with in bodies having a long, fine after end and a propeller located well clear of the hull.

For Condition 2, the after body lines are such as to break up the column of water flowing to the propeller, so that it is working in water more or less broken up by eddies and which may also contain considerable quantities of free air. This condition produces the loss that is ordinarily called "thrust deduction" or "augment of resistance," and reduces the propulsive efficiency below the tank efficiency.

For Condition 3 the diameter may be limited to a dimension smaller than that indicated by Condition 1, while the revolutions remain the same. In this case the tip speed will be lower than in Condition 1, the column of water acted upon by the propeller will be smaller in cross-sectional area, the velocity of flow of the water in the column will be increased, the indicated horse-power per revolution will be increased from that of Condition 1, but the apparent slip per revolution will be increased over that existing for Condition 1, the pitch and surface of the propeller also being increased over that of Condition 1, a net loss in efficiency of propulsion resulting.

By scanning the above conditions it is seen that a propeller may operate under any one of the following conditions:—

1. Under Condition 1—maximum efficiency.
2. Under Condition 2—maximum efficiency decreased by thrust deduction.

3. Under Condition 3—maximum efficiency decreased by diameter reduction.

4. Combined Conditions 2 and 3—maximum efficiency decreased by both thrust deduction and diameter reduction.

The greater number of single-screw cargo steamers suffer the losses as in 4, and these losses are greatly aggravated where the midship section is fined down at the expense of the after body lines, and where the designed revolutions of the propeller are low, thus aggravating both sources of loss.

In the case of the Tyler, the effect of the full midship section was to reduce the thrust deduction to a minimum for that block coefficient, while an analysis of the propeller indicates that the reduction in diameter of propeller was practically nil, thus escaping this latter serious source of loss.

The vessel reflects great credit on both the naval architect who is responsible for the design of the hull, and the engineer who designed the propeller and machinery.

THE CHAIRMAN:—Is there any further discussion? If not, Mr. Rigg, do you desire to reply?

MR. RIGG:—Mr. Chairman and gentlemen, in regard to Professor Peabody's question, as to how we got the ship loaded, I think the explanation is twofold. The first part of the answer is the first two lines of the second paragraph of the abstract, which reads as follows: "In view of the endeavors being made to-day to improve the propulsion of vessels, it is refreshing to meet and do business with owners who are sufficiently keen to have models towed and proper trials run." That is one part of the difficulty settled—the willingness of the owners to do it.

The other part of the answer, perhaps, needs a little explanation. It is not always easy to get ships to a suitable measured mile course without interfering too much with their regular run. This vessel runs from New York to Norfolk, the ship was loaded at New York and then run down to the Delaware Capes on the regular run south, and she there spent a few hours standardizing. Not all ships are on a route so handy to a suitable trial course. She was detained at the Delaware Capes for only a few hours, and afterwards proceeded to Norfolk, Va.

I am glad to hear Captain Dyson's comments on the paper, and am sorry he is not here with us. In reference to his remarks as to the full midship section and fine ends, I need do no more than refer you to the naval constructor's paper read here this morning, and although the paper has not been at my disposal very long, I have made a hurried reference to the curves which are contained in that paper, and find that the Tyler runs within two per cent of Naval Constructor Taylor's most efficient midship section. Captain Dyson, as most of us know, has done a great deal of valuable work on screw propellers lately, and we all should be grateful for the very liberal way in which he places the results of his work at our disposal.

THE CHAIRMAN:—Gentlemen, this practically completes the work for to-day. The meeting will stand adjourned until ten o'clock on Friday morning.

THIRD SESSION.

FRIDAY, DECEMBER 12, 1913.

Vice-President McFarland called the meeting to order at 10.20 A.M.

THE CHAIRMAN:—Gentlemen, we will resume our session with the reading of the paper which was postponed from yesterday, because we anticipated the presence of gentlemen of high standing in the government service whom it was desired to honor in that way. Unfortunately, these gentlemen have not been able to attend, and we will therefore proceed with paper No. 8, entitled "The Evolution of the Lightship," by Mr. George Crouse Cook. In the absence of Mr. Cook, the paper will be presented by the Secretary.

The Secretary presented the paper.

THE EVOLUTION OF THE LIGHTSHIP.

By George Crouse Cook, Esq.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

INTRODUCTION.

Of the many writers who have discussed the subject of sea marks none appears to have assigned to the lightship a place wholly commensurate with its importance as an aid to navigation or an example of engineering skill. A visit to the Library of Congress, Washington, D. C., first indicated this, because I was there unable to find the specific title "The Lightship." Inquiry and search, however, yielded many references in the evolution of this aid to navigation, from which I have assembled the more important facts and endeavored to place them in logical order. This record is far from complete, but it is my intention to add to it from time to time until I have the full story of this bravest of little ships.

The lightship is a beacon by day, a platform for the light by night, and a sound signal station in time of fog. As a day mark, it may have any form; it can carry a light which throws out an unvarying beam to the horizon, and bear fog signals of any type. Its efficiency in these capacities is established. In addition it has certain important functions which are indicated in the following paragraphs:

The lightship may be stationed in deep water many miles from land, and mark a point from which arriving and departing vessels take bearings to proceed to their destination. The Nantucket Lightship, now moored in 180 feet of water 43 miles from the nearest land, has been the landfall of transatlantic trade and travel since 1855.

The lightship may be moored on shifting shoals and banks where no foundations for fixed structures could be laid. When the danger point of the shoal shifts, a corresponding change is promptly made in the position of the light. The Gull Stream Lightship on the Goodwin Sands off the southeast shore of Kent is an excellent example. Nantucket and the Goodwins, with other points, similar in many respects, have always been marked by the lightship.

The landfall of the city of Milwaukee was marked by North Point Lighthouse only for many years. Many wrecks were due to vessels holding in to the shore to pick up the light and avoid running by the city. Now Lightvessel No. 95 stands three miles off the harbor entrance. It is an aid of strictly positive character, showing the approaching mariner a place of security rather than warning him from a danger point. His vessel will necessarily remain afloat where the lightship

itself is safely riding. He cannot run ashore when standing in to pick up the light, nor does his safety depend upon calculating his distance from the signal. The light showing the true way is more useful than the one merely marking a danger to be avoided.

The lightship may be a place of refuge for a crew in distress. Small boats from a ship which has met disaster nearby may reach the lightship, when they could by no means live through the surf and reach the shore. In 1892 the French authorities recommended the replacement of certain lightships with gas buoys; certain of these changes were accepted by the sea-faring public without criticism, but against others the strongest protests were received. In the case of the Plateau des Minquiers the committee appointed to take evidence on the protests learned the cause. It was not the inferiority of the gas buoy's light but discontinuance of the shelter afforded by the lightship in certain stresses of weather and tides.

One of the necessary aids to navigation is the fog signal. The sound of a bell, whistle, or siren coming from a lightship well out from shore necessarily reaches vessels farther out at sea than those proceeding from the land. There are no sound shadows to lessen the effect of the lightship fog signal nor is any part of the sound wasted by being thrown inland. The lightship signal, however, is heard from the land, and guides the ship putting out from harbor, as well as that seeking its way in.

The transmission of submarine bell signals is highly satisfactory from a lightship. Their range and accuracy of direction give to this form of signalling additional importance every year. Not only do these signals travel faster and farther than in air, but at the depth where the bell is hung their successful transmission is not prevented by the heaviest gale. Practically every ship of importance is now equipped with receiving instruments and enabled to pick up these signals from lightships when all others fail.

The lightship with the latest radio equipment is invaluable as a relay station. Its position, at the centers of the lanes of sea travel, enables it to pick up and pass on messages which otherwise would fail to reach their destination. This equipment also enables them to flash to life-saving stations notice of vessels in distress. During the winter of 1912 the most severe storm of years swept along our Atlantic coast. Many wireless shore stations were destroyed. The shipping on the coast sought sheltered harbors, but Lightvessel No. 94 on the Frying Pan Shoal hung on at her moorings, showed her signal lights, and transmitted all messages with absolute regularity. The radio fog signal is now in course of development.

In many cases the lightship serves as a pilot station. An example is the La Plata indicating the passes south of the river of that name. "Pilots are always to be found on board."

The lightship has universal application. It can become mobile or fixed at any time as occasion requires; the moorings now in use make it practically permanent in its given place, while allowing it to be removed without trouble to another anchorage when this becomes desirable. It is available at any time to meet any

emergency. It has been moored near a lighthouse in course of construction and could be used again there if the lighthouse were destroyed.

The lightship has been, and, no doubt, will again be driven from its station. Instructions, issued at Washington in 1829, direct masters "* * * not to ship or cut the cable, or suffer it to be done, in any event, and if the vessel should be likely to founder, to abandon her with his crew * * *." The lightship never voluntarily leaves its station.

Many years ago Robert Hamblin proposed to substitute the lightship for all English lights. His proposition fell through, but not by inherent fault, because there are but few lights to-day which could not be promptly and satisfactorily replaced by lightships. Its adaptability is general. There is no rock or shoal in river, lake or sea which cannot be efficiently marked by it.

THE EARLY LIGHTSHIPS.

The lightship is essentially a product of modern times. It had, as in the case of all modern products, a prototype in the ancient world. This was the Roman coastguard galley which existed in the last few centuries before Christ. The galley carried at its masthead an open framework basket in which a fire was sometimes burned at night as a signal light. The galley thus lighted and manned by an armed crew patrolled the Roman coasts and served as a guide and protection to approaching vessels. But for such a patrol the pirates who invested the coasts would have carried their depredations into the very harbors themselves. The sighting of the light galley was therefore doubly welcome to the mariner arriving from a voyage. It showed that his destination was near and that his ship and cargo were safe from the elements and capture.

After this brief record, then, the lightship, if so it may be called, sinks into obscurity for many centuries. The lighthouse, however, which was both its predecessor and contemporary along the shores of the Mediterranean, was continued through the Dark Ages as the sole aid to navigation.

In these lighthouses illumination was effected by open fires of wood or coal without reflectors or protection other than iron frames which were sometimes placed around the fires to prevent dispersion of the fuel. The smoky gleam of these beacon fires was feeble at best and there was no attempt to reflect it in the proper directions. Often on stormiest nights, when the need of a light was the greatest, none was burning; and there was nothing characteristic in the fires themselves to aid in distinguishing one light from another.

In fact, it does not appear that any material improvement was made during the interval from the erection of the Alexandrian Pharos in 300 B. C., to the building of the Cordonan and the first Eddystone commenced in 1584 and 1669, respectively.

Passing over this interval, then, we note that apparently the first plan for a sea mark other than these lighthouses was for a floating light off the English coast.

Let me quote from W. J. Hardy, who, after making an elaborate study of the question, published in his book, "Lighthouses," the following:

"* * * in 1629 * * * persons petitioned the king for license to light the Goodwin Sands. * * * After setting forth the dangers of the sands in the usual terms, they state that they are ready, in order to warn vessels of those dangers, to maintain at their own costs, 'a light upon the main' at or near the Goodwins, 'whereby every meanly skilful mariner' could, on the darkest night, safely pass the place of danger. * * * 'upon the main' must here mean the main or open sea, especially as the words 'at or near the Goodwins' immediately follow: that expression cannot refer to the mainland, 8 miles off at its nearest point, for lights at the two Forelands were then already established, and the expression 'on the main' would not have been used if a tower built on the sand had been intended. There is, I think, but one way of interpreting this * * * that is, * * * for a floating light or lightship at the Goodwins."

It is therefore fair to say that the first positive sea mark contemplated by the English was the lightship, although the first Eddystone Lighthouse was finished in 1700, thirty years before the project which ultimately established the lightship was put forward.

By 1730 the work of lighting the coasts of England had been, to a great extent, assumed by the well-known Trinity House Corporation. The introduction of the lightship, however, is due to two men, Robert Hamblin and David Avery, who were regarded by that body as mere adventurers. Hamblin obtained a patent from the Crown in 1730 permitting him to establish lightships along the coast. Unwisely, he proclaimed his intention of displacing all other sea marks with lightships, and the Trinity House looked upon his efforts as an infringement of its privileges and opposed them with all means at its command.

The result was a general cancellation of the Hamblin patent, with exception of the rights to a few stations which he had already sold to Avery. By a little diplomacy Avery obtained the good-will and co-operation of Trinity House, and in 1732, at the east end of the Nore Sands in the estuary of the Thames, established the first modern lightship.

The characteristics of this vessel were those of a small fishing sloop (Plate 52). Two small lanterns, burning oil with flat wicks, were carried at the extremities of a yard. The light was dim at its best, and the lanterns were so defective that the flame was frequently blown out in stormy weather. Then, too, the violent pitch and roll of the vessel often snapped the lanterns bodily from their lashings, and the vessel itself chafed its hempen moorings and broke them again and again.

In spite of these defects the first lightship proved itself indispensable. A similar vessel was stationed on the Dudgeon Shoal in 1736, and its lanterns were especially arranged to distinguish it from the Nore. Thus it appears that the now general use of characteristic lights for all beacons originated on board the lightship.

The breaking of moorings and loss of lanterns, so common with these early ships, led to the first improvements. These consisted in the use of heavier anchors attached by chain cable in lieu of hemp, and in the construction of a lantern which fitted bodily about the mast. Robert Stevenson, in his "Account of the Bell Rock Lighthouse," speaks of this type of lantern as an innovation on his Bell Rock Lightship, stationed off the eastern coast of Scotland in 1807. There is, however, in the Trinity House Museum, London, a model representing a lightship built in 1790, which is fitted with lanterns of this kind. It may therefore be, that either Mr. Stevenson was in error, or that this model represents the vessel not as built, but as it appeared after being fitted with the lantern invented by him.

Disregarding these improvements entirely, however, we find that the lightship represented by the Nore and Dudgeon was firmly established as an indispensable aid to navigation. In 1790 the Newarp Shoal Lightship, presumably that referred to above, was stationed off Yarmouth, and in 1795 the famous Goodwin Sands off the southeast coast of England were marked for the first time, as they have been ever since, by the lightship.

The question whether or not Robert Stevenson, the first of the distinguished Scottish family to devote his genius to the lighthouse service, introduced the mast encircling lantern, is of little moment in the view of the improvements which he added to it on the Bell Rock Lightship. His record of this vessel is also the most ample of any concerning these early lightships, and the paragraphs necessary for its history are well warranted.

In 1806 the British Parliament empowered the Commissioners of Northern Lighthouses in Scotland to construct a lighthouse on the Bell Rock, a dangerous sunken reef to the north of the entrance to the Firth of Forth. The Act also authorized the collection of dues for lights immediately upon the location of a successful signal at the rock.

In order to profit by the collection of these dues, the Commissioners decided at once to moor a lightship there. This was the first one on the Scottish coast. The work was intrusted to Robert Stevenson, who, as the Engineer of the Commissioners, was to direct the construction of the lighthouse. He purchased in Leith a fishing schooner, captured from the Prussians, fitted it out as a lightship, and gave it the name Pharos. The vessel was 67 feet length by 16 feet beam by 8 feet depth, and of 82 tons register. The hull was extensively rebuilt, three short masts were erected, sails were provided, and accommodations arranged for crew, lighthouse workmen, and officers.

The lanterns were made in two complete vertical sections and so screwed together as to encase the mast, along which they were free to slide up or down. Each lantern was then fitted with ten oil lamps having small silver-plated reflectors. The lamps were "agitable" or upon hinges so that they could be turned readily for trimming or cleaning. These lanterns, as a whole, were absolutely secure in their position on the mast regardless of the movement of the vessel. They could be readily hoisted, and the light could never be hidden by the supporting mast.

Lanterns of this type proved so successful that they were adopted for all lightships, and only in the past few years have they been generally superseded by fixed lanterns at the masthead.

The anchor of the Pharos weighed about one and one-half tons. It was of the mushroom type, and, to quote Mr. Stevenson, it resembled "in form, as nearly as may be, the vegetable from which it takes its name." Fifty fathoms of 1½-inch chain and 120 fathoms of hempen cable were supplied, the cable being veered out in unfavorable weather.

The vessel was placed on her station in July, 1807, and after several months' test was duly advertised as an aid to navigation. The lights "when seen from either side have the appearance of a triangle, but if seen end on, they appear as two lights, the one above the other." Thus a distinctive light was obtained. The day signal consisted of a blue flag with a lighthouse in the field, and a bell was tolled as a fog signal.

The full-bodied form of the fishing vessel, the absence of a cargo, and the weight of the lanterns aloft caused the vessel to roll violently. In spite of this the vessel held its station, burned its lights, tolled its bell, and produced revenues until the completion of the lighthouse early in 1811.

The Pharos was another striking demonstration of the efficiency of the lightship. In fact, the Pharos may be considered a developed lightship. After this date improvements came thick and fast, and the history of further development must consist in the general description of typical ships.

The lightship may be considered as made up of the hull, the moorings, the illuminant, the lighting apparatus, the fog signal, and the means of communication with the outside world. The evolution of the hull is made the chief subject of this paper, and it may now be traced to the present status.

Before taking up these details, however, we may find it interesting to note how readily other nations followed in the use of the lightship with lanterns and apparatus similar to those on the Pharos.

In the United States, lightships were first authorized early in the year 1819. At this time Congress made an appropriation for two vessels to be stationed at the Wolf Trap Shoal and Willoughby Spit in lower Chesapeake Bay. The vessel for the latter station received first consideration. As it was the "first object of the kind in the United States" great care seems to have been given all preliminaries. Many persons were called in consultation, and a strange variety of opinions was obtained. These ultimately resulted in the award of a contract on September 2, 1819, to John Pool, Hampton, Va., for the construction of a vessel to make the "first attempt to establish a Floating Light." In accordance with the contract it was "to be of 70 tons burthen; copper fastened, and coppered, * * * : to be provided with * * * a cabin with at least four berths, * * * ; and an apartment for cooking; spars, a capstan belfry; a yawl and davids, * * *," and so on in considerable detail. Chain moorings were supplied and some 30 tons of ballast carried. There were certain changes in design and delays in construc-

tion, so that the vessel was not stationed until the summer of 1820. It was found to be too small for wholly satisfactory service in the exposed waters of Willoughby Spit, and was moved to a more protected station off Craney Island. A larger vessel was built for the original station.

The idea of the lightship, however, seems to have taken a positive hold upon those in authority, and in 1820 three more were authorized for southern waters. One of these was detailed to replace the first vessel on Willoughby Spit. In 1822 an appropriation was made for the first lightship off New York Harbor, at Sandy Hook. In 1823 $25,000 was made available for the construction of a lightship of not less than 250 tons to be stationed off Cape Hatteras. Thus the most dangerous of American shoals, the Diamond, was first marked, as it is to-day, by the lightship.

Practically all of these vessels were most efficient aids to navigation and fully demonstrated their worth. At one or two extremely exposed and trying stations, moorings were frequently broken, and in 1827 the Diamond Shoal was driven ashore; but the lightvessel continued to grow in favor, and in 1841 there were thirty in service. Notwithstanding the number at this early date, there are but few illustrations or drawings which can be truly associated with a particular vessel of the time. These few, however, give a fair idea of the largest of these vessels, and enable us to understand the report of the master of an early Sandy Hook vessel, that it rolled so as to "heave the glass from the lanterns."

The French Government lighted the Talais Bank with its first lightship in March, 1845. It was of 80 tons, and carried a black day mark 14 meters and a fixed light 10 meters above the water line. A bell was carried as a fog signal.

A plan of a Trinity House vessel of 1845 is given in Alan Stevenson's "Account of Skerryvore Lighthouse," London, 1848. It was a vessel with bluff ends and wide flaring sides, and fitted with two bilge keels on each side. The dimensions were 80 feet in length on the water line, 21 feet in breadth at the deck, and a burden of 158 tons. The lanterns were octagonal in form, 5 feet 6 inches in diameter, and fitted with eight Argand lamps in the focus of parabolic reflectors. The moorings consisted of 1½-inch chain cable and a single mushroom anchor of 32 hundredweight. The crew numbered eleven men.

Belgium's first lightship was established on the Daedemarkt Bank in 1848. It was fitted with one lantern containing eight lamps having red lights. The lamps were suspended on the cup and ball gimbal principle. The moorings consisted of two anchors, of 17 quintals English weight, with 70 fathoms ground chain, and 120 fathoms chain to the ship from a swivel at the middle of the ground chain. The vessel was also supplied with signals to communicate with the shore, a non-sinkable lifeboat, and carried a crew of eight men. During the first twelve years of its service, the ship remained on the station, except for absences for cleaning and painting, when in 1860 the cable parted in a storm and had to be renewed.

An equally important early French vessel is the Ruytingen which was stationed in the North Sea off Gavelines. The vessel was 82 feet length, 21¼ feet beam,

and tonnage of 150. It carried one light at a height of 34½ feet above the water line on a mast located about amidships, and was moored by two anchors weighing 2,650 pounds each.

Another interesting and valuable record is that of the United States Lightvessel No. 1. It was the first constructed under the military board which for many years had direction of the Lighthouse Service, being built in 1855 at Kittery, Maine.. The ship began its service on Nantucket Shoal, where its light was the first, and, while its design was to an extent empirical, as was the case of vessels of the time, it proved a success in every way. Lying in as exposed a station as held by any lightvessel in the world, it stood the buffeting of the North Atlantic for many years, and is to-day on the important station of Martin's Industry off the shores of South Carolina.

So new lightships appeared here and there throughout the world, until in 1860 there were approximately 136 in service. Great Britain came first with 48, the United States second with 39, Russia third with 12, then Germany with 8, Denmark and India with 7 each, Australia with 5, France with 3, Belgium and Sweden 2 each, and British America, China, and Turkey 1 each.

These numbers have been further increased from time to time as the needs of navigation demanded and available funds allowed, so that to-day there are approximately 800 lightships scattered even more generally throughout the world.

It may also be noted that Japan established her first lightship in December, 1868; only fourteen years after the historical visit of Commodore Perry of the United States Navy. The vessel was of English design built by native workmen. It was fitted with a fixed red catoptric light in a lantern sliding along the mast, and served to mark the channel in Yokohama Bay.

THE EVOLUTION OF THE DESIGN AND CONSTRUCTION OF THE HULL.

All vessels can fulfil two of the three leading functions of the lightship, those of the day beacon and sound signal station. The third, however, that of a light platform, is most difficult of attainment. And it is mainly with respect to this function that the evolution and improvement of the vessel itself take place, and in the ship of to-day, steadiness and ease of motion are the first requirements.

Many of these early ships were discarded trading schooners or fishing vessels, adapted to the service as in the case of the Pharos. They were modified, of course, to carry the lanterns and accommodate the crew, and sometimes carried ballast sufficient to represent a normal cargo. It is evident from the general type of these vessels, built originally to carry a load on a minimum draught, that they were exceedingly poor light platforms. The light draught and small displacement with a full body and water line gave them a great metacentric height, which, combined with the weight of the lanterns, and, I believe, the general absence of bilge keels, caused them to roll excessively. The pitching was violent in proportion, and it is not surprising to read, as we do, of the lanterns being snapped from their positions on the yard and the moorings carried away.

The results obtained from vessels built to serve as lightships were but little better, for, strange as it may seem, the science of ship design dates from scarcely fifty years ago, and these ships were but the product of arbitrary judgment of the builder or designer. The chief characteristics of the vessels were much the same in all cases, and I found again and again reports of the trying nature of life aboard, and even of the discarding of a vessel, owing to violent movements which rendered it uninhabitable, to say nothing of inefficiency as a light platform.

In 1856, a paper, "The Form of Stationary Floating Bodies," was read at the Institution of Civil Engineers, London, proposing a circular vessel for a lightship. The discussion which followed developed a wide diversity of opinion as to what form was the most desirable. All the opinions expressed appeared to be founded on assumptions only. Scott Russell, the distinguished naval architect of his day, spoke at some length and said that he "would be inclined to give a lightship great length, with a safe but small section, and extremely fine lines."

Again in 1860 the question of lightship design received serious consideration in England. A "Royal Commission on Lighthouses" was appointed to inquire into matters pertaining to the lighthouse service. In the course of its investigations it sent out a series of questions to the distinguished "scientific men" of the day, including Rankine, Faraday, Herschel, etc. One of these questions referring to the lightship called for "Opinions on the best form for the hull." The replies were most varied, and showed the indefinite state of the science at the time. Some advocated longer vessels, others shorter; some recommended much sheer, others less; some favored bluff bows, others sharp, etc.; while several advised circular hulls moored at the center of gravity. Among the advocates of the last was Professor Rankine, of the Glasgow University.

A second question, "At what part of the vessel should the moorings enter," elicited a variety of opinions; and hawse holes at a considerable height above the water, close to the water, and also under the water, were proposed.

M. Leonce Reynaud, a former Director of the French Lighthouse Service, explains the design of the early French lightships in his "Memoir" of 1864. He writes that "the vessels are narrow as compared with their length, so that they may offer as little resistance to the waves as possible; in the forepart of the vessel their lines, which below the water line are very sharp, spread out above in such a manner as to give them great buoyancy; the perpendicular section through the middle is almost rectangular; finally bilge keels placed on each side of the vessel run nearly the entire length, and are designed to reduce the rolling motion as much as possible."

So the lightship, as a ship, continued with all ships, as a product of opinion merely, for many years. To prevent rolling, it was sometimes fitted with bilge keels. Often there were so many that their efficiency was reduced, and they greatly increased the resistance of the hull and consequently the pull upon the moorings. Other excellent features of design, such as a ballast, for instance, were used to improve the performance of the ship, but used with such a lack of knowledge of their true properties that they actually impaired the general efficiency of the vessel.

Beginning in the middle of the last century, elaborate series of experiments with ships and models were taken up in England and France, and served to establish the true theories of ship design. An invaluable series of these experiments was that conducted on various naval vessels in England by the Admiralty in furtherance of the theory of stability, as brought forward by the distinguished naval scientist Froude in 1861. These experiments, extending over a period of ten years or more, proved to a great extent the relation of the form of hull, metacentric height, inertia, and rolling keels, to the movement of a vessel. The importance of these relations was gradually recognized, and they were made the basis of design for new ships.

These relations were still further emphasized by another series, which was apparently the first conducted on the lightship itself. They took place in 1888 on the Nouveau Dyck stationed off the French coast near Dunkerque. The Nouveau Dyck was a converted fishing vessel, heavily ballasted, and it rolled and plunged so violently that it was practically uninhabitable, to say nothing of its poor qualities as a light platform. An exhaustive study of the causes of this excessive movement was then taken up. Many observations were made on the period of waves at the station, and it was found to be fairly constant. Then, observations on the period of oscillation of this vessel, which had a metacentric height of nearly 4 feet, showed that it synchronized with that of the wave. Various trials proved that the vessel's period could be increased most by raising and stowing the ballast at the sides of the ship. By this means the metacentric height was reduced to 2½ feet and the period doubled. The synchronization was thus stopped, and the vessel so improved in its performance that it was held in service.

Repeated demonstrations of this nature so established the necessity of considering these principles that lightships are rarely built now without preliminary investigation along the lines indicated. Individual engineers in different countries have often selected certain of these principles and featured them in their design. Bilge keels and inertia ballast figure prominently in the French lightship Le Sandettie, built in 1902. Some 16 per cent of the 341 tons displacement is in ballast, so placed in a deep keel that it adds greatly to the inertia and radius of gyration of the vessel, and, together with deep bilge keels, gives it a long period of roll. Le Sandettie has been made the subject of many interesting articles by its designers, and complete descriptions of the vessel may be found in the publications of many of the scientific societies and nearly all of the maritime journals issued at the time of its completion.

The form of a number of recent U. S. lightvessels is such that the wedges of immersion and emersion in transverse rolling approach equality, while the metacentric height has been reduced to a minimum of 12 inches, and the movement of the vessel thereby greatly steadied. Bilge keels have been fitted, without being featured, but inertia ballast has not been generally used.

The ultimate object of design is, of course, to include the use of each element to the extent best calculated to control both rolling and pitching. For this pur-

pose each must be made the subject of special study with reference to a moored vessel. During the past few years, Mr. George Idle has made many observations and experiments on the rolling of Irish lightships. In papers read before the Scientific Society of Ireland in 1911, and the Institution of Naval Architects of London, in 1912, he gives much valuable information on the forms and effects of bilge keels for lightships. He finds that properly designed and located bilge keels are of the greatest value in reducing both the amplitude and period of roll; and the results of his work appear to show that they are an economical and convenient means of obtaining the greatest results for the smallest expenditures. It is scarcely necessary to say, however, that bilge keels alone cannot make an ideal light platform of a vessel, and that the vessel of the future will include each element of design developed as Mr. Idle has developed the bilge keel, and in this work I shall endeavor to play a part.

In the more practical features of design the same effort for improvement has been continued. These early lightships were built of wood, and some of them staunchly built. The English lightship at the Nore, built of oak and ash in 1804, was examined by Mr. Idle in 1889 and found to be in excellent condition. The U. S. lightship on Bush Bluff Station dates from 1849, and its oak is sound and hard and should be good for many years. These ships, however, are exceptions to the general rule. In 1856 the Fifth Auditor of the U. S. Treasury, in a report on the lighting service, states that the average life of a wooden lightship, as then built, is only five to ten years, with heavy annual cost for upkeep and repairs.

The first marked practical improvement in hull construction was the substitution of iron and steel for wood.

Iron was used as a structural material for shipbuilding purposes at an early date. In 1843 the Trinity House discussed and rejected its use for their lightships and it was not until 1857 that they adopted it in a vessel built for service on the Goodwin Sands. The Mersey Dock Board, however, was more progressive, and the first iron lightship appears to be that stationed by them on the North West Shoal below Liverpool in 1845. The vessel was 98 feet long and normally drew 8 feet 6 inches. Its tonnage was 203. The hull was subdivided by three watertight bulkheads, and fitted with a deep bar keel, and two bilge keels on each side. Three lights were carried at different elevations, and a lattice daymark was fitted on the mainmast. Notwithstanding the highly satisfactory performance of this vessel, many objections were made to the use of iron. It was feared that they could not be made strong enough to withstand the shocks received by a vessel at anchor in a rough sea; that they would suffer more severe damage than a wooden hull if driven ashore; that the interior of the hull would sweat and become damp and unwholesome; that its cost would be prohibitive; and that the bottom would foul very rapidly. In all but the last, experience has ultimately proved the opposite to be the case, but the wooden lightship continued in general use for many years.

The advantages of iron as a structural material, however, were being con-

tinually demonstrated in general shipbuilding practice, and were finally forced upon the lightship. Its first permanent use in the service came in a combination of an iron frame and wooden planking for the hull. Of these composite vessels, a typical illustration is that of the British Lightship Puffin, built in 1887 for the Commissioner of Irish Lights. The vessel was designed for an exposed station on a stormy part of the Irish coast, and special care was taken to make it both seaworthy and habitable. The length over all was 101 feet 6 inches, length between perpendiculars 93 feet 6 inches, moulded breadth 20 feet 9 inches, and the moulded depth 11 feet 10 inches. The iron frame carried an inside skin of 3-inch teak, fastened to the frames by ⅞-inch galvanized bolts and an outer skin of the same thickness and material, which is fastened to the inner with ¾-inch copper clenched bolts. Four bilge keels were fitted to reduce rolling. The moorings consisted of two lengths of 1⅞-inch cable, one of which was connected to a large mushroom anchor, while the other was fastened to a Troatman anchor lashed to the side, and ready to be cut away should the first fail. The day signal consisted of two large balls, each 6 feet in diameter, mounted one over the other. The light was carried in a lantern house 8 feet in diameter, which encircled the mast and was capable of being raised and lowered. The light revolved and was operated by clockwork in the 'tween decks.

A variation of composite construction was that wherein the iron or steel plating of the hull was sheathed throughout with wood. By this means the interior of the hull is somewhat protected from the effects of sudden changes and extreme temperatures. The plating also is stiffened by the bulk of the wood against sudden local shocks or blows, which might otherwise bilge the hull. An illustration of this sheathed construction is given by U. S. Lightvessel No. 43, built in 1881, which has given many years' excellent service at South Pass, La. The vessel is 110 feet 9 inches long, by 25 feet 8 inches beam, and 11 feet 6 inches deep, with a gross tonnage of 191. It has a complete watertight iron hull, carried to the main deck and entirely sheathed with 3 inches of yellow pine planking. Aside from this distinctive construction, the vessel is an excellent type of the first-class American lightship of the day, and while this sheathing serves its intended purpose, the advantages do not generally warrant the increase in cost of labor and material involved.

A second variation of the composite construction is that in which the steel framing of the hull is covered in part with wooden planking and in part with steel plating. The U. S. Lightvessels Nos. 68, 69, 70, and 71 built in 1897 for stations on the Atlantic and Pacific Coasts were of this type. They are vessels of the first class in dimensions and characteristics. The framing, stem, stern, and keel, a bilge strake, and the topside plating were of steel. The entire bottom, from the line of the main deck down, was planked with white oak and sheathed with composition. All have occupied stations of the first importance, and are still in constant use despite extended service on the Diamond Shoal and other equally exposed stations.

The French authorities appear to have been cautious in adopting iron for lightship construction. It was not until 1891 that a vessel, the "new" Ruytingen, was built entirely of this metal. It was 30 meters in length, 7.82 meters in breadth at the deck, and of 338 tons displacement. A distinctive feature of design is the use of cast-iron bilge keels, which serve their usual function and have a secondary steadying effect due to the inertia of their "winged out" position.

For a number of years from the dates just noted, both composite and wooden construction were in common use. Experience with the metal of the composite vessels taught the crews what care was necessary for its satisfactory preservation, and by 1900 authorities had generally accepted steel as the only material suitable for lightships at important stations. There were still, of course, some advocates of wood, and, as recently as 1902, a first-class U. S. lightship was constructed of wood and stationed off the Maine coast. This lightvessel, No. 74, is 118 feet long, 28 feet 6 inches beam, 14 feet 7 inches deep, and of 495 tons displacement. Two cylindrical boilers and a single cylinder propelling engine of 380 indicated horse-power were fitted to make the vessel independent of a convoy, and in all fittings and equipment no expense was spared to produce the best results. The framing of the hull was of the best selected white oak and the planking of yellow pine; the hull is copper fastened generally, and sheathed to a point well above the water line.

The lightship of steel construction, as illustrated by a recently completed vessel for the U. S. Service, Lightvessel No. 94, now stationed on the Frying Pan Shoals, N. C., is fully described and illustrated at the close of this paper.

A second practical feature of design, which has greatly increased the general efficiency of the lightship, is propelling machinery. This alone enables the ship to proceed to its station without a convoy, and also to ease off the strain on its moorings by steaming up into a heavy storm; or to return to and stand by the station marking buoy in case the moorings are actually carried away. An earnest recommendation that vessels be equipped with propelling machinery was made to the British "Royal Commission on Lighthouses" as early as 1860. It appears however, that the proposition received but little attention, and I find no evidence that lightships were so equipped before 1891. At that date three second-class lightships were built for the U. S. Service, Nos. 55, 56 and 57, 90 feet by 20 feet by 9 feet and 130 gross tons, and fitted with propelling machinery. This installation was of but little power, consisting of but a single non-condensing engine, with a cylinder of 14 inches diameter and 16 inches stroke, and one marine fire-box flue boiler carrying 100 pounds pressure. But it was a proof of utility, and now many vessels of size, on important exposed stations, are fitted with compound engines and one or two boilers.

The propelling plant of a first-class U. S. lightvessel in present service consists of a vertical, surface condensing, compound engine, with cylinders 16 inches and 31 inches in diameter, and a stroke of 24 inches, driving a four-bladed propeller 7 feet 9 inches in diameter, and of 10 feet pitch. Steam is supplied at 100

pounds by two gunboat type boilers, 9 feet 3 inches in diameter, and 16 feet 4½ inches long. Under fair conditions some 360 indicated horse-power is developed and a speed of 10 knots obtained.

The actual usefulness of such a plant has been again and again demonstrated in emergencies, and its absence has been the indirect cause of many a disaster. One such case was that of a German lightship at the mouth of the Elbe, which broke from its moorings and was driven helplessly ashore. All members of the crew were lost. The utility of the propelling plant may be better judged, however, by the fact that the U. S. lightvessel in the strong current of the Gulf Stream, over the shifting sands of Diamond Shoal, has steamed on an average of over 300 miles per month throughout the period of a year.

Another important improvement in design consisted in fixing the lanterns permanently aloft, and was suggested, no doubt, by their early increase in size and weight, which made it difficult to raise and lower them as required for their proper operation. This plan, also, is an old one. It was proposed in England in 1845. Reference to the files of the U. S. Bureau of Lighthouses discloses the fact that a similar proposal was made there at about the same time for a vessel with two lights fixed aloft. It seems this proposition was more favorably received than many early ones now so universal, for Major Eliot, of the U. S. Lighthouse Board, reported in 1873 the construction of a lightship in England fitted with a hollow steel mast containing a ladder inside for access to the lantern.

A variation from the tubular steel mast is that of one built of angles or other structural shapes. The first of this type proposed is found on a plan submitted to the U. S. Lighthouse Board in 1873 by Henry Lepaute, Constructeur, of Paris.

Lanterns fixed aloft upon one mast or the other, of these types, are now generally employed in all new work. The latest development of the open work class is used on the U. S. Lightvessel No. 44, which has been recently fitted with these masts, and stationed at Northeast End, New Jersey. The present tubular type was brought into current use by the French on the Talais of 1896, and it is similar in general characteristics to those proposed in 1845. Its use is also shown on the plates of the U. S. Lightvessel No. 94, published herewith.

In all the main parts of the lightship meant to accommodate the crew, who spend their lives on board, and add to their comfort, the greatest progress has been made. One of the most important steps was taken in fitting the vessel with a complete upper or spar deck, extending throughout its entire length. Nearly all early ships were but single-deck vessels, in which the crew lived on a lower deck or platform below the water line. The first step came in the building up of the sides of the vessel forward, and the laying of a forecastle deck to protect the windlass, and such parts of the quarters as could be placed there. An extension of this forecastle, both in length and height, naturally followed, and in 1894 U. S. Lightvessel No. 58 was built with an entire upper or spar deck. In such a design, the quarters for both the officers and men are placed on the main deck, well above the water line, and they

have the advantages of more air, lighter, fresher, and drier quarters, while the lower platforms are given over exclusively to stores. Not only does the spar deck improve the vessel in this respect, but also the higher freeboard adds greatly to the range of stability, and thus assures a safer and drier ship in times of severe weather.

Beyond this point improvements have been made in all the lesser features of design adding to the comfort of those on board the vessel. On a first-class U. S. lightship, there is little lacking that could add to comfort and convenience in so small a vessel. There is a stateroom for each officer and each two of the crew. The vessel is steam heated throughout; fresh and salt water is carried throughout the ship in the most modern plumbing, for cleaning and sanitary purposes; baths and toilets are fitted; and it is quite safe to say that the crew find conveniences equal to, if not better, than those in corresponding positions in other employments.

U. S. Lightvessel No. 94, Plate 53, which has been mentioned in the preceding text, may be taken as an illustration of the degree to which this type of craft has been developed. It was completed and placed upon station at the Frying Pan Shoal, N. C., in 1911, and still remains the latest and most highly developed addition to the fleet, although new vessels are now under construction which will be equipped throughout with internal combustion main and auxiliary engines.

The vessel was designed under the direction of Mr. George Warrington, Chief of the Division of Marine Engineering, U. S. Bureau of Lighthouses, and possesses the following general dimensions and characteristics:—

Length over all	135 ft. 9 in.
Length on the sixth water line, from the after side of the stem to the forward side of the stern frame	112 ft. 11 in.
Beam, moulded	29 ft. 0 in.
Depth of hold from top of main deck beam to top of keel amidships	15 ft. 4 in.
Displacement (moulded) at 12 feet 9 inches mean draught in salt water, 660 tons	
Signal light fixed white:	
Elevation above water	68 ft.
Range of visibility	14 miles
Candle-power	2,900
Fog signal:	
Steam chime whistle	12 inches
Blast	5 seconds
Silent	55 seconds
Hand and submarine bell.	

The lines of the vessel, Plate 54, are the development of many years' observation on the performances of these small vessels as signal light platforms when moored at sea. The character of the body plan is such that the wedges of immersion and emersion in transverse rolling are nearly equal and the usual impulse of

excess buoyancy is thereby avoided. Fore and aft the lines are full, and experience seems to warrant the practice, although the argument might be offered that a vessel with finer ends would lift less quickly on a passing wave. The feeling among seamen, however, appears to be against a vessel which might be frequently awash in heavy weather. Further details of the form characteristics are shown on Plate 55 by the curves of displacements, centers of buoyancy, coefficients, metacenters, centers of gravity with varying conditions of load, etc., etc.

The vessel is constructed of steel with the conventional structural elements, shown in Plate 56, of the midship section. The scantling throughout is much heavier than that required by any classification society for a vessel of the size, in order that the greatest practicable strength be obtained, as well as sufficient material to bear the heavy corrosion brought upon a vessel liable to extended periods of continuous duty in exposed waters.

The arrangement of the hull, as shown in Plates 57 and 58 of the inboard profile and decks, is that of a continuous upper-deck vessel, subdivided below the main deck by watertight bulkheads into six general divisions. The first of these is also subdivided horizontally to form a trimming tank and store for paints, oils, and articles of a similar nature; the second compartment contains the chain locker, fresh water tanks in the hold, and general store rooms on the lower deck; aft of this compartment, and extending entirely across the vessel and to the main deck, is the coal bunker, which opens into the fire room through watertight vertical sliding doors. Another complete bulkhead separates the boiler room from the engine room, aft of which the vessel is further subdivided on the line of the lower deck to give an after trimming tank and lower-deck storage rooms.

The entire forward section of the main deck is given to the anchor-handling gear which is of absolute importance in a vessel of this class. It consists of a manger, into which the main central hawse pipe of the mooring anchor and chain opens, and while plugs are fitted about the chain in the pipe, it has always been found desirable to separate this portion of the deck by a watertight breakwater, and drain the space by large scuppers as shown. Immediately aft of the breakwater are two plate foundations carrying the chain compressors and springs, from which the chains lead directly to a large double steam windlass of standard manufacture. The crew's quarters are separated from the windlass space by a light divisional bulkhead and consist of staterooms for the men, galley, pantry, toilet, bath, and mess room. The gangways abreast the machinery room casing are fitted with work benches, tool lockers, etc. The quarters for the officers, who on a light vessel are usually workers as well as executives, occupy the after portion of the main deck of the vessel. The master and engineer have staterooms of considerable size, each fitted with desk, locker, wash basin, etc., while those of junior officers are nearly as complete. A chart room, pantry, mess room, bath and toilet complete this section of deck. The vessel is heated by steam throughout, and hot and cold running water supplied to the galley, bathrooms, and all officers' staterooms.

The spar deck forward is protected by a high bulwark which shelters the man

on watch and the emergency fog bell. The latter is used when the steam fog signal is out of order. The forward deck-house supports the bridge and is fitted as a general chart and watch house; the after house is given over exclusively to the radio outfit. Two boats are carried in cradles on the spar deck as shown.

The outboard of the vessel is shown in both the photograph of Plate 53 and the drawings of Plate 59. The chief characteristic and distinguishing mark, aside from the unusual sheer and freeboard, lies in the steel tubular foremast which carries a cylindrical lantern at its head for the protection of the signal light. The necessary rig is fitted for three sails, and topmasts are fitted from which a radio antenna is swung at an elevation of 82 feet above the water.

The signal light consists of a fourth order lens carried upon a compound pendulum mounted upon gimbals in the lantern as shown on Plate 60. The adjustment of the top and bottom counterweights on the pendular apparatus, which is some 9 feet 6 inches in height, enables a period of oscillation to be obtained much longer than that of the vessel itself, and the extreme movement of the vessel itself is transmitted to the pendulum in but a slight degree. The lens, therefore, stands quite steadily upright and shows a beam of light truly to the horizon except under abnormal conditions. A fixed white light is shown, which is obtained by an incandescent oil vapor lamp. This lamp consists of a reservoir of kerosene under a pressure of about 60 pounds, which ejects the oil through a heating tube, where it is vaporized and from which it is thrown as a vapor upon a mantle which becomes incandescent under the heat of the flame.

More recent installation of similar pendular apparatus, made upon older vessels undergoing repairs, has the gimbal suspension made up of knife edges, and much more sensitive adjustment and correspondingly greater steadiness are thereby obtained. Such installations have also been successfully fitted with electric lights.

The main propelling engine consists of one vertical, direct-acting, open-front, surface-condensing, fore-and-aft compound engine, with cylinders 16 inches and 31 inches in diameter, and a piston stroke of 24 inches, as shown in Plate 61.

Steam is furnished by two boilers of the Scotch type, Plate 62, 10 feet 6 inches mean diameter and 11 feet 4 inches long, carrying a working pressure of 110 pounds per square inch. The propeller is of cast steel with four blades, 8 feet in diameter and with 10 feet pitch. On trial the vessel steamed at 9.9 knots with 380 indicated horse-power, and readily developed a speed of 9¼ knots under normal conditions with an indicated horse-power of 300.

The performance of the vessel upon its station has been most satisfactory and with a metacentric height ranging from 17 inches to 9 inches between the full load and light conditions, a duration of period and range of movement has been obtained which is most satisfactory. The high topsides also render the vessel seaworthy under extreme conditions, and the indications of the curves of statical and dynamical stability shown in Plate 63 are found to be fully realized in service.

DISCUSSION.

THE CHAIRMAN:—In connection with this paper on "The Evolution of the Lightship" some of the members present must surely be from concerns which have built lightships for the government, and it would seem that they might be prepared to discuss this paper. A great deal of care and labor has been spent in its preparation, and we would like very much to have Mr. Cook's efforts receive the appreciation of a good discussion. I did not intend, by referring to the builders of lightships, to suggest the exclusion of those who had not built them, and some of our distinguished architects, both of the Navy and the merchant marine, might be able to discuss the points presented in the paper, particularly the one on which Mr. Cook asks enlightenment, the best form of hull and where the moorings should enter.

MR. E. A. STEVENS, JR., *Member:*—There is one thing I notice particularly in this paper. Mr. Cook asks for an expression of opinion as to where the moorings should enter the hull, or, in other words, the position of the hawse pipes.

I happened to be looking over an old copy of the report of the Secretary of the Navy, which had an account of the loss of the Trenton and Vandalia during the gale at Samoa. I noticed that the commanding officer of the Trenton stated that the disaster was partly due to the location of the hawse pipes; whether he wanted them higher or lower, I cannot recall. The question, however, was raised, and Mr. Cook has raised it again, and I think it may be an interesting subject, not only for lightships, but other ships that are required to be anchored frequently, especially in open waters.

THE CHAIRMAN:—As a matter of historical interest, I will say that I cannot imagine the position of the hawse pipes had much effect on it, although I was not on the ship at the time of the disaster. I had served on all three of the United States vessels that were there, but I left the Vandalia a month and a half before the disaster. The fact is that the Trenton and the Vandalia went aground and pounded to pieces, and it would not have made much difference where the hawse pipes were. The position of the hawse pipes may have hastened the end, but it was sure to come in the terrible seas which were raging at that time. Is there any other gentleman who desires to comment on this paper?

MR. ARTHUR D. STEVENS, *Member:*—I will say in connection with this paper that I had the privilege of repairing Lightship No. 4 last year, and one of the strong criticisms made was that when she would shear in a current, and bring her cable across the bow, she would list very seriously, lie over and be a long time recovering. I simply mention that as a criticism which the men on board made.

THE CHAIRMAN:—Was the hawse pipe too low or too high?

MR. STEVENS:—I am simply giving you the criticisms of the men on board as to the heeling action that happened to be mentioned here, on Lightship No. 4. They criticised it as giving her a serious list when she sheared in the current, athwart the cable beam.

MR. ELMER A. SPERRY, *Member:*—I do not know that I can throw much further light on this subject, as a whole, but one phase of it interests me, naturally. You understand that

within the last year the world, especially Great Britain and the United States, has been doing a great deal of research work in the rolling of ships, and the question arises whether this midship section given on Plate 54, as designed, is the best selection of midship section to resist rolling of an anchored ship. It so happens that our Navy has been pushing forward research into this problem further, I believe, than any other navy. This important work includes investigations in determining the relations of shapes and body form to rolling. We all supposed that a log would not roll in waves—there is no form line or pendulum that the waves can get hold of. Naval Constructor Taylor finds, however, that there is a condition in which a log may be made to roll when subjected to the action of waves. In his investigation, which extends over quite a large number of models, some of the forms of which were given in his paper presented at this session, he finds, I understand, that there is a large difference in the rolling of these models with a given wave force impressed. It would therefore seem to me that this, which is probably the most searching and far-reaching work on this subject that has yet been undertaken, and by far the most practical, as it has all been conducted actually in water, should be consulted before the final lines are determined upon for ships of this class.

Professor Goold H. Bull, *Member*:—I had the honor of serving on the Trenton for one cruise and part of another, part of the cruise in which she was lost, and the hawse pipes were a source of trouble during all of her sea experience. We had to fit jackasses—jackasses are simply big plugs made of manila rope—these jackasses were fitted in the hawse pipes when we were at sea and at anchor. During a pampero in Montevideo Harbor, which was probably nearly as strong as the gale at Samoa, the surging of the chain would loosen the jackasses and they had to be fastened several times, but the water was coming in through the hawse pipes all the time. We lost a man during the anchorage at Montevideo through that cause. The loss of the Trenton was not due to that entirely, but to the fact that she lost her rudder early in the gale, and they could not steam out on that account, otherwise I think she would have been saved. From what I saw of hawse pipes placed low, as those were, on the gun deck, it was rather a faulty construction in that case.

Mr. F. L. DuBosque, *Member of Council*:—It would seem to me that a lightship would require no hawse pipes; the factors which would cause a ship to change her position seem to be the effect of the currents, waves and winds, and it appears to me that the mooring should be attached to the stem lower than the usual hawse pipe permits. A line drawn between the center of lateral resistance and the anchor would seem to show the correct position of the attachment to the stem.

If the fore foot were cut away as much as possible I believe yawing would be reduced. Our experience in towing shows that the tow-line should be attached to the towboat as far forward of the rudder as possible. If attached at the stern the rudder has very little effect.

Dr. F. A. Kolster, *Radio Division, U. S. Bureau of Standards* (Communicated):—Mr. Cook's mention of the possible use of radio signalling apparatus on lightships and in lighthouses for the purpose of transmitting signals during fog is of great interest and importance.

The most serviceable and important field for radio-telegraphy lies in promoting safety to life at sea and aiding navigation.

The lightship equipped with suitable radio apparatus is an exceedingly valuable signal station if properly operated and used to full advantage. During a fog, characteristic radio signals should be automatically sent from lightships and lighthouses. In cases where it is practicable to do so, the radio signal and fog-whistle could be simultaneously operated, thus enabling a ship within range to determine its distance from the lightship or lighthouse with a fair degree of accuracy by noting the interval of time between the reception of the radio signal and the fog-whistle.

Signal lights fail in fog, the sound of the whistle is often deflected or reflected, but the radio signal is practically instantaneous no matter how thick the fog or how severe the gale.

Mr. G. H. Blaker (Communicated):—Several months ago the writer had a conversation with Mr. Cook concerning the installation of direct-connected electrically-driven oil units in lieu of the present steam plant used in lightships.

The writer has had before him since that time the drawings and plans of a first-class light-vessel similar to the one illustrated in this paper, but has been so very busy upon other matters that it has been practically impossible to do anything else than outline such an installation.

As the writer understands the matter, it would take as minimum about 300 horse-power to handle one of the lightships. It would appear, therefore, that the ideal installation for the lightship, so far as economy of operation is concerned, would be to install that 300 horse-power in two units—either two 150-horse-power engines direct-connected to direct-current generators, or one 200-horse-power engine and one 100-horse-power engine, these engines to be connected at the switchboard so that they could be operated in parallel.

The propeller should be driven by a slow-speed reversing motor, which could be controlled from the pilot-house, absolutely independent of the engineer, and therefore all that the engineer would have to look out for would be the engines, which would maintain constant speed under all conditions.

As the writer understands the matter there are some days that it is necessary for the propeller to be turned over slowly, in order to keep the drag off the chains, or anchors, which hold the boat, and in that case the 100-horse-power engine could be operated for 24 hours, if necessary, at a minimum cost of delivering all of the power that is necessary to propel for that service. If the next twenty-four hours required twice that, the 200-horse-power could be put into service, or, if the full power required, both the 200 and the 100, and the full power delivered to the motor which operates the propeller. The controller in the pilot-house operates in the same way practically as a controller is operated in the ordinary large street car.

At the same time that the 100-horse-power engine is in operation, such storage batteries as are required for lighting of the service lamps and the lighting of the vessel could be charged, and it might also be found practical and feasible to install a fair-sized storage battery to operate the bilge pumps, the fresh-water pumps, and such light machinery as might be called upon for intermittent service. A motor-driven winch for hoisting the anchor could also be installed without much difficulty, and at the time that the power was not required the whole outfit could be idle for several months during the summer, if necessary, and the power could be available, by having the quick-start oil engine, in from two to three minutes, if it is required.

In other words, as the writer sees the matter, it would obviate the necessity of carrying steam, at working pressure, 24 hours per day, seven days a week. It would obviate the carrying of much coal, as for the same horse-power required the oil would weigh half that of the coal. Therefore, double the amount of energy could be stored upon the same ship in the same space.

It might also be found practical, instead of running the large engine to charge the storage battery, to put in a small set, three or four kilowatts; for charging the batteries and for lighting the ship, it is quite possible that the smaller of the two large engines would run often enough to keep the batteries well charged.

The electrically-driven propeller would make the outfit as flexible as any steam plant, and probably more flexible, and would be directly under the control of the operator in the pilot-house, so that instant action could be had at any time. With the installation of the two sets it will obviate almost entirely the possibility of a break-down.

Mr. Cook (Communicated):—Although not a member of the Society, I regret that I was unable to attend the meeting and in person express my obligation for the generous attention bestowed by the Secretary during the preparation of this paper, and the courtesy of the Chairman and the various members who have considered the question here raised.

I should have been glad indeed to receive the suggestions of shipbuilders and architects who have built or designed vessels of this class, and would have presented such suggestions to the proper authorities in connection with the designing of new lightships now under consideration at Washington, so that a closer understanding between the two interested parties could have been reached.

With reference to the loss of the Trenton and the Vandalia, mentioned by Mr. Stevens, I concur in the opinion of the Chairman that conditions will arise which may defeat the best efforts in design and construction, and we can but do our best to make the possibility of defeat a remote one. Our Lighthouse Service met with such a loss in the hurricane of last November, when Lightvessel No. 82, off Buffalo, N. Y., foundered. The wreck has not yet been found and an adequate analysis of the causes of the disaster cannot be made; but the violence of the storm was such that many other and larger vessels were also lost. With regard to the position of the hawse pipe itself, I believe that the elevated pipe, as noted by Mr. Stevens, is decidedly objectionable in the case of a small vessel in a strong current.

I had understood that Naval Constructor Taylor was contemplating a series of experiments on the rolling of vessels, and it is of great interest to learn from Mr. Sperry that this work is actually under way. Mr. Taylor has very kindly spoken with me on the form, rolling, and pitching of light vessels, and I trust that we may learn more from him as a result of these experiments, which are of so comprehensive a character.

The entrance of water through the hawse pipe is a source of great annoyance on the modern lightship, as in the case of the Trenton, mentioned by Mr. Bull. Jackasses of various pliable materials have been tried, but were ground to pieces by the movement of the chain, which, on a light vessel, is free to play over a range of several feet against the action of the compressor springs, shown on Plate 58, with the surging of the vessel. A cast steel ball-and-socket plug is now being designed to attach to the moving chain in way of the hawse pipe, which, it is believed, will obviate this fault to a great extent. Several such plugs will be supplied to a vessel, so that if the chain is paid out hurriedly in bad weather,

another may be attached to stand in the pipe at the point of final adjustment of the chain. These extra plugs will then be removed when the chain is brought up to its normal mooring length, and before it passes through the compressors, and they will then be stowed away for the next occasion.

Mr. DuBosque's suggestion that lightships be constructed without hawse pipes, and that the moorings be attached as far as possible from the rudder, is highly interesting. It is to be feared, however, that the relief gained from the annoyance caused by the entrance of water through the omission of hawse pipes would scarcely offset the many difficulties which would result from such omission, as changing the moorings, paying out extra cable in bad weather, etc. The correctness of his opinion relative to the desirability of attaching moorings as far as possible from the rudder is amply proved by the fact that this has become a nearly universal practice. In Lightvessel No. 94, and most other United States ships, the actual attachment of the chain is well inboard, but the effect on the chain of the hawse pipe as fitted is practically that of an attachment at the very stem itself.

The communication of Dr. Kolster touches on a project which, when perfected, will enable vessels to determine their exact positions in the heaviest fog with great certainty. Dr. Kolster refers merely to that elementary phase of the radio-signal which consists in the use itself of the signal, but I understand that both he and the officers of the Radio Service of the Bureau of Steam Engineering, Navy Department, are working on the development of apparatus to indicate the direction of the source of a radio signal. Such an instrument, placed upon a vessel, may receive messages from two adjacent headlands or points, and by plotting the direction of each, the position of the vessel may be determined with precision.

Mr. Blaker's proposal to equip a vessel with an electric power plant is in the direct line of modern progress. The electric signal light and electrically-driven auxiliaries are being installed on the new vessels now under construction for the United States Service, and they are replacing other systems in the extensive overhauling of certain other vessels. Then, too, many ships are equipped with radio sets and electric ship light systems, so that it would be but one more step to use this power for the propelling system itself. I certainly trust that Mr. Blaker will place his proposal in such definite form that it may be submitted to the lighthouse authorities for serious consideration in connection with the designing of new vessels now in course of preparation. I feel that a project of this kind from Mr. Blaker could be carried out with complete success.

I wish to acknowledge again to the Society my deep appreciation of the privilege it has extended to me in the publication of this paper, and express the hope that it may be the medium through which I shall be enabled to complete the story of this bravest of little ships.

THE CHAIRMAN:—If there is no further discussion, we shall pass to the next paper. We will now take up Paper No. 11, entitled, "Strains in the Hull of a Ship at Sea and Those Measured while Receiving Cargo," by Mr. James E. Howard.

STRAINS IN THE HULL OF A SHIP AT SEA, AND THOSE MEASURED WHILE RECEIVING CARGO.

By James E. Howard, Engineer-Physicist, Bureau of Standards.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

Strain gauge measurements were made on the plates of the shelter deck of the S. S. Ancon, of the Pacific Railroad Steamship Company, on a voyage from New York to Colon and return, and subsequently during the time the ship was taking cargo aboard at New York.

The Ancon, originally called the Shawmut, was built by the Maryland Steel Company, Sparrow's Point, Md., in 1902. It has the following dimensions: Length, 505 feet; beam, 58 feet; depth, 41 feet; di placement at 30 feet draught, 20,830 tons.

It has twin screws and is equipped with triple expansion engines of 24-inch, 39½-inch, and 62-inch diameter, 45 inches stroke, making 78 revolutions per minute. Steam pressure carried, 200 pounds.

The ship makes about 12 knots per hour.

For a time the ship was used in the China trade, but of late in the transportation of structural materials for the Panama Canal, of which cement usually formed the principal part of the cargo.

Live load strain measurements were made on the deck plating while the ship was at sea, using a new type of extensometer designed by the writer, a scissors gauge, so called from the resemblance of its working parts to a pair of scissors. Figure 1, Plate 65, is an illustration of this gauge, nearly full size.

It consists of two beams, which, taken together, are rectangular in outline, and between which are located two small bell crank levers. Parallel motion of the beams is secured by the use of flexible stay plates. The bell crank levers are mounted upon fulcrums made of thin plates of tempered steel. They work in opposite directions. The long arms of the levers are blades which make with each other a small angle, the vertex of which or point of intersection of the blades marking the place where the reading of the instrument is taken.

The blades are comparatively light; the beams are relatively heavy. The instrument is dust proof. The proportions of the parts are such that a change in the position of the point of intersection of the blades of one inch in length represents a movement of the beams, or measured movement of one-thousandth of an inch. The index plate is graduated into ten parts, each representing one ten-thousandth of an inch. A change in position of the point of intersection of .01 inch on the scale represents one one-hundred-thousandth of an inch movement of the beams. The gauge has a total range of movement or full scale reading of one-thousandth of an inch.

Since the range of the instrument is quite limited it is necessary to establish longer or shorter gauged lengths on the measured member according to the expected magnitude of the strains in order that they shall not exceed the capacity of the instrument. On the present occasion the strains were generally small, and it was expedient to use extension rods which covered a length of 6 inches on the deck plates. The gauge is shown in position on the deck in Fig. 2, Plate 65, where it appears spanning a lap joint, stepping down from one plate to another. Contact with the deck plates is made by means of conical steel points attached to the beams or to the extension rods. Sufficient roughness was found on the deck plates to actuate the instrument when a weight was placed over each contact point, as illustrated in Fig. 2. The contact points would be placed in small holes made with a center punch in the deck plates if needed.

Moderate loads causing strains of a few hundred-thousandths of an inch, or slowly applied loads, can be measured with comparative ease, but the effects of rapidly changing loads of considerable magnitude are less easily observed. The instrument is a new one and was used for the first time on this voyage. A number of modifications in its details will be made to facilitate taking readings, making it even a little more compact, and providing means for attaching it to different shaped members and in different positions.

It responds promptly to changes in strains in the member under examination. Stamping upon the deck at a distance of 25 feet from the gauge caused longitudinal vibrations which the instrument responded to. The results here presented are regarded as close approximations to the actual strains which were developed but are not held to be rigorously exact.

A strain gauge of the type shown by Fig. 3, Plate 66, was used for measuring the deck plates during the time cargo was being received. The gauge employed had a working length of 20 inches. It is telescopic in design. There is an outer tube which carries a conical contact point near one end of the instrument, and an inner bar which carries a contact point near the opposite end. The longitudinal movement of the inner bar with reference to the outer tube, and consequently the movement of the contact points, is measured by a screw micrometer attached to the outer member. The contact points are inserted in small drilled and reamed holes made in the deck plates, and, when thus centered, readings with the micrometer are taken.

The gauge is used in connection with a steel reference bar made of the grade of structural steel, and lengths on the deck are referred to this standard bar and recorded in terms of it. Concerning manipulative features, check observations, when the instrument is used under favorable conditions, commonly give the same ten-thousandth of an inch reading of the micrometer. In engineering structures in general it is not expected to define stresses much nearer than 500 pounds per square inch, which corresponds to a strain of three and one-third ten-thousandths of an inch in 20 inches length.

The deck plates of the ship afforded a better opportunity than usually experi-

enced in making strain gauge measurements on engineering structures; therefore it is believed that these results are trustworthy in a higher degree than generally expected, that the strains were substantially as reported. In deducing the stresses corresponding to the measured strains, a value of 30,000,000 pounds per square inch was used for the modulus of elasticity of the steel plates.

A full cargo of 10,217 tons was carried on the outward voyage, while on the return voyage the cargo was only 3,000 tons.

Observations on the live load strains of the deck plating were made on both the outward and the return voyages. Good weather generally prevailed, hence the measured strains refer to conditions as they were found on a smooth sea with a minimum pitching of the ship. A few observations, however, were made on the outward voyage with a moderate sea running. With a low freeboard, when the ship carries a full cargo, the decks were generally wet in a moderate sea, and without protection it was impracticable to make many observations. The few measurements which were taken showed strains of increased magnitude, corresponding to the greater pitching of the ship which then occurred.

Tables 1 and 2, Plates 71 and 72, give the results of the measurements made at sea. Certain of these measured strains are entered upon diagrams of the deck plates and appear in Plate 67.

Referring to the observations in detail, and beginning at the forward deck, neither the solid metal of plate C 27 (Table 1), over which the breakwater passed, nor that of the next plate aft developed strains of sufficient magnitude to be measurable. At the first lap joint aft the breakwater and across all succeeding joints there was measurable deformation. The solid metal of plate C 25 and those aft displayed measurable longitudinal strains due either to the vibrations of the engines or to the pitching of the ship or to their combined effect.

The magnitude of the strains in general increased as the bulkhead of the superstructure was approached, although the rate observed was not a uniformly increasing one. The presence of hatches probably influenced the magnitude and distribution of the stresses. The smooth sea was favorable for acquiring comparative results on different parts of the ship. At times the engines on one shaft would gain in the number of rotations over those of the other, and differences in strains were noted which were attributed to the effects of the heavier pistons when those of both shafts were in the same phase.

Strains across the lap joints of courses C and D were substantially the same and much greater than those of the stringer plates. This behavior calls for the development of longitudinal shearing stresses at the seams between the stringer course and the adjacent course, but measurements necessary to follow these shearing strains were not included in the present series.

Pitching strains were not of sufficient magnitude to admit of measurement on the deck amidship, covered by the superstructure, but those caused by the engines were followed to a point nearly abreast the boiler hatch.

On the after deck the strains reached a maximum near the bulkhead. The

movement across one of the lap joints exceeded the scale reading of the gauge, and was estimated to be ± .00125 inch. Strains due to the engines were greater than those due to the pitching of the ship, both forward and aft the superstructure. This remark concerning the relative effect of the engines and the pitching of the ship refers to the observations made on the outward voyage. North bound, with a light cargo, the relative effects of the engines and the pitching were reversed over those of the outward voyage, the pitching strains now predominating.

A comparison of results of the outward and return voyages is shown on Plate 68. Whereas on the outward voyage a strain caused by the engines of about .00125 inch was observed at the lap joint of course C next the bulkhead, on the return trip the effect of the engines was hardly perceptible at that place, but the pitching of the ship caused a movement estimated at three times the scale reading, or ± .003 inch. At other joints and on the solid plates similar results were observed, the pitching strains greatly predominating on the return voyage. All measurements were taken along the middle of the width of the several courses of plates.

Strains due to pitching and those due to the engines were recognized by their periodicity. The engines made 78 rotations per minute and strains attributed to them were developed synchronous with the rotations.

In explanation of the relatively large movements due to the pitching of the ship when in comparatively smooth water, it appears probable that the lap joints of the deck plates had become loosened in a degree by exposure to repeated stresses. A portion of the movement observed not unlikely represented slip of the joints. Of the effects which came from the engines there would be some 700,000 to 800,000 repetitions during one voyage to the Isthmus.

Places on the deck where the greatest longitudinal strains occurred were not usually accompanied with marked vertical vibrations. At least certain places where vertical vibrations were most pronounced, under the feet, were examined without finding unusual longitudinal strains. On the deck over the ridge bar on the starboard side, and also near the main mast, were places of pronounced vertical vibrations, but where the measured strains were of moderate extent. Again, at the stern, near the bitts, the vertical vibrations were very marked, while the longitudinal strains in the vicinity were not measurable.

The stresses corresponding to the measured strains, observed on the forward deck, ranged from 100 pounds to 650 pounds per square inch. On the after deck, 2,250 pounds per square inch was found, all referring to measurements made on a smooth sea. The stresses reached a maximum in the vicinity of the bulkheads of the superstructure and disappeared as the bow or the stern was approached.

The observations which were made prior to the main series, when a moderate sea was running, showed stresses on the after deck near the bulkhead ranging from 2,500 to 3,500 pounds per square inch. The highest stress observed was on the bulwark rail, where a stress of 5,500 pounds per square inch was found. Fig. 4, Plate 66, shows the place occupied by the strain gauge on the angle of the rail when this observation was made.

The measured strains represent changes in length of the plates, and it was obvious at the time of their development which they were, whether they were in a tensile or a compressive direction as the gauge successively opened and closed, but pre-existing strains in a finished structure at repose defy definition. In order to ascertain what strains exist in different parts of the ship, of tension and compression or zero strains at neutral zones, it is necessary to establish reference lengths initially on the component members and remeasure them at desired stages. It involves considerable work to acquire reliable information upon the distribution of strains in the principal members of a ship when launched, with the machinery installed, with a cargo aboard, and finally the live loads at sea, but it is entirely feasible to acquire such data and in fairly complete detail. The method of measured strains devised by the writer, which has been used in the investigation of internal strains in steel forgings since 1887, and more recently in the investigation of strains in engineering structures, admits of furnishing this information. This method of investigating strains was employed on the present occasion in measuring the deck plates during the time the ship was receiving cargo.

The purpose of making the strain gauge measurements at the time of taking cargo aboard was primarily to ascertain what strains resulted directly from loading the ship. Notwithstanding the intent of the observations, the results evidently showed effects which were chiefly due to changes in the temperature of the plates, with obscure effects, if any, attributable to the cargo. With stevedore work going on at the several hatches, few places on the deck were accessible at all times or available even in the early hours of the morning, when most of the measurements were made. The places selected were just aft the bulkhead, as shown on Plate 69. Reference lengths were established, of 20 inches each, on six courses of plating, three on each side of the ship, and one on each bulwark rail. The latter were on the angles directly over the double-riveted butt-strap joints of the bulwarks. All reference lengths were fore and aft in their direction.

Measurements were inaugurated soon after the ship came out of dry-dock, and were continued until the day of sailing. The diagram, Plate 70, has entered upon it the results of these measurements, also the temperature of the deck at each of the places measured, the hour of the day, and the draught of the ship forward and aft.

On June 13 the ship was at dock in Brooklyn, with bow heading east, on June 15 and 16 at Communipaw with bow toward the west, and on succeeding days at Pier No. 52, North River, with the bow heading east. These changes in position introduced differences in thermal conditions which doubtless influenced certain of the measurements.

On the morning of June 20, sailing day, the temperature of the deck was nearly uniform, the range being from 64° to 67° F. For convenience, the stresses were regarded as having zero value at that time, and the state of strain or strains on other days is given with reference to those on the day of sailing.

The manner in which the strain gauge readings were taken and results arrived at were as follows:—A reading is taken with the strain gauge on the reference bar,

followed by a reading with the gauge on the deck plate. The distance or gauged length laid off on the deck is thus determined with reference to that laid off on the reference bar, the strain gauge being used as a transfer instrument to compare one gauged length with another. The reference bar is assumed to have a length of exactly 20 inches. The temperature of the reference bar and that of the deck is noted. If they are not the same the reading for the deck length is corrected to correspond with that of the reference bar. The latter is made of structural steel or steel of that grade and assumed to have the same coefficient of expansion as the deck plates.

Assuming the strains to have zero value on the deck plates on some given day for comparison, on this occasion taking the lengths as they were measured on the 20th of June, the individual lengths are said to be in tension or compression on other occasions according to their corrected lengths, that is, according to whether they were longer or shorter than on the day selected for comparison. Referring to examples on diagram, Plate 70, the corrected gauged length of stringer plate No. 10, port side, on June 13 was .0019 inch shorter than it was on the 20th. The force required to shorten the plate this amount is 2,850 pounds per square inch compression. On June 16 the same gauged length, corrected, measured the same as on the day selected for comparison. It therefore had zero stress upon it with reference to its state on June 20. Again the gauged length was .0008 inch longer on the 18th than on the day selected for comparison, which strain corresponds to a stress of 1,200 pounds per square inch tension.

The results exhibited on diagram, Plate 70, were deduced in the manner described. Where stresses of tension are shown on the diagram the corrected gauged length on the deck was longer than it was found on the day selected for comparison, namely, June 20. Where stresses of compression are shown the gauged length was correspondingly shorter.

There was no change in the cargo between the time of measurements of June 15 and 16, but a wide difference in temperature, accompanied by a wide difference in the stresses. The starboard stringer plate passed through a range from 2,550 pounds per square inch compression to 1,050 pounds per square inch tension, a total of 3,600 pounds per square inch. This and other changes which occurred between those dates were clearly temperature effects.

Significance is attached to the similarity between the shaded parts of the diagram representing the stresses in the stringer plates and bulwark rails on June 13 and June 15, comparing the port side on the first day with the starboard side on the second day. The ship was moved between those dates from Brooklyn to Communipaw, and turned half around. Both days were sunny, and it would seem that the effect of the sun on the port side when at Brooklyn was closely reproduced on the starboard side when at Communipaw.

The state of the strains on the mornings of June 16, 19 and 20 was nearly the same. In the meantime, cargo was received which increased the draught from 12 feet 6 inches to 26 feet 6 inches forward, and 19 feet 6 inches to 27 feet 6 inches aft.

It is not improbable that some effect resulted from taking this amount of cargo aboard and bringing the ship nearly to an even keel, but the part belonging to temperature effects and that belonging to the cargo do not admit of being separated.

On the 20th of June the usual complement of readings was taken in the morning, supplemented by observations on the bulwark rails during the day, the temperature in the meantime having risen from 60 degrees to 90 degrees on the starboard side and 62 degrees to 87 degrees on the port side.

On the starboard side the stress changed from 900 pounds per square inch tension to 1,650 pounds per square inch compression, and on the port side from 450 pounds per square inch tension to 1,950 pounds per square inch compression. These changes again clearly represent temperature effects.

Higher stresses were developed in the more rigid stringer plates and the bulwark rails than in the plates having lap joints, a result to be expected whether caused by temperature changes or by taking aboard the cargo.

The maximum range in stresses observed were 4,800 pounds per square inch on starboard stringer plate No. 10 and 4,050 pounds per square inch on the corresponding port stringer plate. The range in temperature for all places observed was from 60° to 116° F.

Four of the gauged lengths spanned joints in the plating. There was greater apparent rigidity in the butt joints of the stringer courses than in the solid plates, and less rigidity in the lap joints of courses C than in the solid plates. Dotted lines on the diagram connect plotted points showing the movements at the joints, located according to the same scale as the plotted strains in the solid plates.

It will be noted, for example, that the changes in strains from June 13 to 15 on the port side were much greater for the gauged length spanning the lap joint of course C than the strains in the solid plate—more than twice as much—while on the stringer course the reverse was true. Here again the general looseness of the lap joints appears in evidence.

Complex thermal conditions prevailed throughout this series of observations, but no more than would be experienced on other occasions. The ship floated in water at about 60 degrees, setting deeper and deeper as the cargo was received, while the temperature of the deck plates reached 116 degrees on one occasion.

In conclusion, attention is invited to the opportunities afforded by engineering structures of all classes in the acquisition of information upon the behavior of materials in service, the distribution of stresses, and verification of computed stresses, along the lines of inquiry illustrated in these strain gauge observations.

DISCUSSION.

THE CHAIRMAN:—It is hardly necessary for me to mention (as I presume you all know) that Mr. Howard is one of the most distinguished men in the world in regard to the testing of materials. For a great many years he did all the testing with the famous machine at the Watertown Arsenal, and an enormous amount of information, on which naval architects, engineers and all other people who use materials have depended for years, has been the result of Mr. Howard's splendid work. Consequently, I feel that the Society has had an unusual treat in hearing this splendid paper by such an eminent man in the profession, and I hope that some of you will show your appreciation of the paper by the discussion.

MR. THOMAS M. CORNBROOKS, *Member:*—This ship to which Mr. Howard refers was originally built for the Boston Steamship Company of Boston, and as those were the first large ships built by our company, I kept in touch with them for years to see if they developed any irregularities.

As confirming what Mr. Howard said in regard to the strains on the rail near the bridge, I remember that Mr. Wiley, superintendent-engineer, wrote me that the only trouble they experienced was at the break of the bridge just at the point where Mr. Howard made observations. Some ten or twelve rivets would loosen. These would be re-driven, and again after two or three months they would loosen again. The bridge shear was stepped down to the rail, and then, about fifteen feet further forward, the side plating was stepped down to the upper deck shear strake.

PROFESSOR C. H. PEABODY, *Member of Council:*—I think that it is quite impossible to overestimate the importance of investigations of this sort, and it is also difficult to understand how so much information can be given in so short a space. This is an investigation giving us information in regard to a subject of the very highest importance, about which, so far as I am aware, we have not had direct information. The ordinary calculations for strength of ship are made habitually for ships of importance, but in a conventional manner, and the results stated cannot be given as being absolute stresses to be expected in a ship at any time. Here we have the strains themselves, and, in consequence, the stresses reported to us from direct observation.

THE CHAIRMAN:—I wish some of our professional members would say a word. This seems to me to be a very interesting and valuable paper, and I hope those members within whose purview it comes, particularly, will have something to say.

PROFESSOR H. C. SADLER *Member of Council:*—I am afraid I cannot add very much to this discussion, but I should like to add my appreciation of the paper. Unfortunately, I have not had an opportunity of reading it up to the present. One point struck me as being particularly interesting, and that was the confirmation of an increase in stress due to discontinuities in the structure. Some years ago Mr. Bruhn, of Lloyd's, read a paper upon this subject, in which he analyzed the effect of discontinuities in structure from a theoretical standpoint, and it is very interesting to see that his conclusions have been confirmed by the experiments reported in this paper.

Another point in the paper, which I think is of particular interest, was the movement of the joint as compared with the movement of the solid plate. It seems rather remarkable, really, that the lap joint should move three to four times as much as the center of the plate.

I think that is a thing which we probably had not realized before, and it is, perhaps, a little hard to understand.

Mr. Elmer A. Sperry, *Member:*—I do not think Mr. Howard should feel that a failure to discuss this paper is any indication of a want of appreciation of its value. I think it is one of the most remarkable papers of the session. The stresses on the deck plates are of rather peculiar nature, and I think there is one point that might shed some light on these stresses, especially the marginal stresses as compared with the stresses along the midship axis as shown by the diagram.

Last year when we were running some tests at sea it became necessary to determine if there were any stresses set up in the hull, beams, or deck structure, due to stabilizing the ship in heavy weather. They crawled in every available space and watched the joints with great care, but the work was done so easily and naturally that no stresses made themselves manifest at any point. After the work was finished some of the joints were opened and examined, which confirmed this. Under these conditions it would have been interesting to have had some of these instruments installed at various points to ascertain the character and direction of the small stresses that had been calculated and were known to exist.

However, there seems to me to be one point that should not be overlooked, namely, the torque stresses. If we take a tube—that is, a long tube—we have a very stable structure with reference to torque moments. If we secure one end of this tube and apply torque stresses to the other it will be found that only a very slight give, or spring, will occur. Suppose we take this cylindrical tube and shave it down horizontally, or saw it in two, so that we have a gutter; now can any one of you imagine what the torque value of that gutter is as compared with the torque value of the tube out of which the gutter was made? Calculations show that it is only 1/3600. Now, then, a ship is a gutter with a deck or decks across it, and it has been known for years that ships, especially ships such as torpedo-boat destroyers, long and slender, and where the plating is as light in thickness as is consistent with safety, will yield quite considerably to warping moments. As we analyze these torque strains, which always come in rough weather, we find that the marginal portions of the deck are the portions which must receive and sustain certain of these strains. This introduces quite a wide variation in the stresses between the marginal and central regions of the decking and should, of course, be taken into consideration in connection with observations such as have been undertaken by Mr. Howard.

In prosecuting investigations such as these it would seem to me that if these instruments could be made recording, being plotted a against time, it would then be possible to trace the cycle of stresses, aiding materially in their proper interpretation.

Mr. Francis T. Bowles, *Past President:*—I suggest that Mr. Howard tell us whether this apparatus of his has been used on other structures to determine live load, and if so, where; in other words, give us some idea of the reliability of the instrument and how he came to make this test on this vessel, and whether he is at liberty to make it on other vessels.

Mr. Francis B. Smith, *Member:*—I ask Mr. Howard if he noted, at the time the boat took on cargo, if the draught of a vessel was affected in the marks forward and aft by the different temperatures of the deck. We have reports of that kind on our ships quite frequently. We are in the Lake trade. When our boats load at the head of Lake Superior and go down to the Sault Canal, where the draught is limited by the draught of water in the

locks, they sometimes claim that the ship is drawing as much as two or three inches more at the ends than she would if the temperature of the sun did not have so much effect on the decks, and I would like to ask Mr. Howard if he noted that. (These boats are six hundred feet long.)

Mr. Howard:—In regard to the features which led up to making these tests, I will say that for some time I have been engaged in the examination of engineering structures, railway bridges, buildings, and pavements and strain gauge observations have been the means by which the information was acquired. In this city, observations have been made on the Bankers' Trust Building, a limited number on the Woolworth Building, on the main columns. The Missouri River Bridge, at Kansas City, afforded an example of strain gauge observations on a large, modern riveted structure. Street pavements of Cleveland, Ohio, and Kansas City, Mo., afforded additional opportunity for observations, and on earlier occasions, very much earlier than these, there were measurements made on rails under the weight of engines, noting the effect of different wheel loads, experiments being conducted on the Burlington, Pennsylvania and the Boston & Albany Railroads. A strain gauge for measuring dead loads was first devised for laboratory work, and subsequently modified for field use, while this small scissors gauge was the last devised. This was gotten up primarily to observe the strains on steel rails under the weights of locomotives and cars—the one here shown (Mr. Howard displays a scissors gauge). Some modifications are expected to be made, and to get it down to somewhat smaller dimensions. It is now only three inches long, and of such shape that it may be put on the base of a rail and observations made at slowly moving loads on the fiber stresses developed.

The question of the accuracy and reliability of the instrument is, of course, one of the first things to be considered. As far as I have been able to judge, it performs the same functions on each occasion. The instrument, however, is not one of the easiest to be read, but modifications will be made which are expected to improve that feature and permit greater certainty about the finer subdivisions. I think if we now measure 1/50000 of an inch reliably we are doing pretty well, but can, under some circumstances, do better.

The gauge was used for the first time on the deck plates of the Ancon. It is arranged, as you will see, with flexible joints. The fulcrum plates are thin, flexible steel plates, so that the instrument can be used where there is considerable dust, as there is no opportunity for dust to get into any of the working parts. The behavior of the gauge, I think, was the same on different occasions. If that were the case, then it comes to a question of calibration or rating of the instrument, and that admits of being done in the laboratory with precision. On the whole, the instrument, or some slight modification of it, seems to be a practicable affair.

In regard to changes of temperature affecting the draught of the boat, no observations were made. The effect on the deck of the Ancon, while receiving cargo, in which there was a change of stress of some 5,000 pounds per square inch, which I attribute to temperature causes, would lead one to suppose that the draught might be changed and made more or less amidships, according to the temperature of the deck. I think that theory would certainly be tenable.

The Chairman:—Gentlemen, I am sure that you will desire to express your thanks to Mr. Howard for his valuable paper, and I should be glad to entertain a motion to that effect. It has been moved and seconded that the Society extend a vote of thanks to Mr. Howard for his very able paper. It is so ordered.

Mr. Lewis Nixon, *Vice-President:*— I arise to make a special motion at the instance of the Council. Ordinarily the Society has taken but little interest, and purposely so, in political questions, but when there are propositions arising in Congress which seem to threaten the very existence of shipbuilding in the country, we feel that if we should let the occasion go by default, and not register a protest, that we ourselves should be to blame.

A few weeks ago a bill was passed by the Senate of the United States called Seamen's Bill 136, which was so radical in its treatment of the crews of our ships, in relation to the officers, and in its relation to the ships generally, that it would undoubtedly end the flying of the American flag on the ocean, certainly on the Pacific Ocean, almost entirely, and for that reason I propose the following resolution:

RESOLUTION REGARDING SENATE BILL 136.

On October 3, 1913, the U. S. Senate passed Senate Bill 136.

This bill is alleged to promote the welfare of American seamen in the Merchant Marine of the United States.

This Society does not concur in the view that a law which makes it impossible to fly the American flag on the oceans in the foreign trade is in the interests of the seamen of the country. It believes that legislation which will hinder the expansion of our coasting fleets and nullify much of the good that will result from the development of our deeper waterways is against the welfare of any of our people.

It is our judgment that, as the result of the enactment of this bill, American vessels will be driven from the foreign commerce upon the Pacific, that trade will be driven to Canadian ports, and that vast damage will be done to our transportation systems on land and sea.

It believes that on account of the demoralization resulting from the false and misleading impressions to be created by such bill as to the relation between the seamen and the officers of our merchant vessels, the hazard of the sea will be greatly added to and that the safety of persons and commodities in transit at sea will be threatened.

The bill is vicious selective class legislation based upon misrepresentations, and which defeats the very object that it is alleged to further. Therefore, be it

Resolved, That the Society of Naval Architects and Marine Engineers, representing the shipbuilding and allied interests of the United States, protests against the enactment of Senate Bill 136, as operating against the upbuilding of our merchant marine, reducing the opportunity of employment of American seamen, adding to the risk of life and property at sea and sapping the commercial independence of the nation.

That a copy of this resolution be sent to the committees having cognizance of Merchant Marine legislation in the Senate and House, and to the Secretary of Commerce.

Mr. Stevenson Taylor, *Past President:*—In seconding the resolution of Mr. Nixon, I wish to add that if this act as passed by the Senate is made a law it will destroy, in a great measure, not only the attempts to improve our merchant ocean service, but will destroy many of the lines engaged in our sound, bay and river service. I heartily endorse the resolution, sincerely hope that it will be passed unanimously, and that it will be sent to the proper authorities to-day.

Mr. E. P. Bates, *Member:*—Before we can vote intelligently on this resolution, it seems to me we should know more of the text of the bill.

Mr. Taylor:—I presumed that everybody knew the text of the act. Briefly, it establishes a class called A. B. S., meaning able-bodied seamen. To be an able-bodied seaman, and to receive a certificate that one is such, a man must have been three years on the deck of an ocean or lake steamer. The law provides, also, that those serving in one department of a vessel shall not be required to do duty in another department. It provides that every lifeboat must have at least two of the so-called able-bodied seamen. It provides that there shall be a sufficient number of seaworthy lifeboats on ocean, lake, sound and bay steamers, to carry every passenger and every person in the crew on board the vessel. There are many other objectionable provisions, but I think I have already named sufficient of them to show the character of the bill.

We all know there are no seamen, as the term "seamen" used to be understood, on our steam vessels—that the persons on deck are merely deck scrubbers, brass polishers, painters of rust spots, and similar work of that sort. The old seaman, the man who could furl a sail, splice a rope, tie a bowline or square knot, take his trick at the wheel and steer the ship, has almost passed away. There are few such on our ocean, sound or bay steamers. We depend on the entire crew of the vessel to man the lifeboats; in other words, the engineers, firemen and stewards are all part of the crew, and have to man the lifeboats. These men are drilled in the handling of the lifeboats, and the boats are well provided with crews at the present time without adding unnecessarily to the number in the crew of the vessel. If you prevent one man in one department from doing duty in another department, except in case of work necessary for the safety of the vessel or for the saving of life in jeopardy, we will have no right to demand that stewards and firemen, or other member of the crew than those on deck, shall take part in the lifeboat drill or fire drill.

I think I have said sufficient to this body, the members of which are well acquainted with the needs of vessels, especially vessels at sea, to indicate that the bill is purely class legislation, in the interest of what is called the Seamen's Union and in utter disregard of other rights. Though not an owner of vessels or any part thereof, I feel deeply on this subject, and think any one who has given it any attention will feel the same. To my mind this Society should take a stand against legislation of that sort.

Mr. William E. Waterhouse, *Member:*—I am in hearty sympathy with what Mr. Taylor has said, and Mr. Nixon preceding him, and I would like to cite a specific case of the effect of this bill. Three weeks ago to-morrow contracts were to have been signed for three excursion boats to operate between the Battery and Glen Island, and at the eleventh hour and fifty-ninth minute the attorney for the bankers who were to underwrite the project called attention to Bill S. 136, and said that under a strict interpretation of Section 12 of that bill these boats would be a losing proposition. The banking support was accordingly withdrawn until Congress had disposed of this measure.

Mr. F. B. Smith, *Member:*—There is another point the gentleman did not bring out in regard to the A. B. S. We might take the definition of an A. B. S. according to this bill—they must have served three years on the deck of a vessel——

Mr. Taylor:—Ocean or lake.

Mr. Smith:—They might never have been in a lifeboat in the three years, or handled

a small boat in any shape or manner. A fisherman on the banks of Newfoundland, brought up in small boats, would not be accepted as an A. B. S., and would not be considered competent to take part in the handling of a lifeboat. A fireman, no matter how well skilled he is in the handling of a small boat, cannot act as a part of this life-saving crew—but any man who has served three years on the deck of a ship would be considered competent, whether he has ever been in a lifeboat or not, according to the bill. Those are the principal points of the bill as it stands now.

Mr. Francis T. Bowles, *Past President:*—I ask when this resolution is passed that it be sent by telegraph to the Committee on Merchant Marine of the House of Representatives.

The Chairman:—Is there any other gentleman who desires to comment on this resolution before we put it to a vote? All in favor of the resolution please say Aye; opposed, No. It is almost unanimous; there was one "No" registered. The Society goes on record as being heartily in favor of this resolution, and the Secretary will carry out the instructions to telegraph this to the Committee on Merchant Marine.

The next business will be the reading of paper No. 12, "Stability of Lifeboats," by Prof. H. A. Everett.

Mr. Everett presented the paper.

STABILITY OF LIFEBOATS.

By Professor H. A. Everett, Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

The following presents the results of an investigation undertaken the past summer to determine the stability of several types of lifeboats in common use on ocean-going ships of these parts. The boats were all stock boats, new, and ready for immediate service.

In its essence, the work consisted of the customary calculations for the curves of statical stability after having made inclining experiments upon each boat to determine the location of the center of gravity. There were four boats and each was inclined in two conditions: (1) light with but the apparatus and the two observers on board, and (2) loaded, with the number of persons which the Rules and Regulations of the United States Board of Supervising Inspectors permit. The work provided theses for two members of the graduating class of the Massachusetts Institute of Technology, A. H. Pitz and C. S. Hsin, and was under the immediate supervision of the author.

Four boats were used; the principal dimensions are given in the following table, and the lines are given on Plates 73 and 74.

Principal Dimensions.

Number.	Type.	Material.	Length.	Breadth.	Depth.	Capacity by U. S. rules.	*Weight, light.	Weight carried when tested.	Corresponding number of persons.	Load displacement.
1	Standard	Metal	28′	8′ 4″	3′ 7″	50 persons	3,584	7,639	51	10,559
2	Standard	Wood	28′	8′ 4″	3′ 7″	50 persons	2,740	7,854	52	9,784
3	Decked	Metal	28′	9′ 4″	2′ 7″	60 persons	5,392*	9,962	66	14,462
4	Collapsible	Wood	29′ top 28′ bot.	9′ 0″	3′ 0″	54 persons	†3,267* 8,840	2,380	16	12,720

*Including experimental apparatus and 2 men. †Before and after launching.

Numbers 1 and 2 were of the standard type of open boat provided with tanks as shown on the lines and were of practically the same external form. Construction plans of these are shown on Plates 75 and 76. Both conform to the U. S. rules with air-tank capacities of 51.8 and 76.4 for the wood and metallic boats, respectively.

Number 3 was of radically different form and falls within the class commonly called decked lifeboats, as the passengers are carried above a second watertight skin or deck. It was built of metal (No. 14 B. W. G. galvanized iron) in accordance with the construction plans on Plate 77. The lower space, with its watertight subdivision, serves at all times as an hermetically sealed buoyant chamber.

Number 4 is called a collapsible boat and consists essentially of a flat pontoon of wooden construction pointed at each end, and provided with wooden thwarts, rail and canvas bulwarks. These all fold down on to the upper deck or can quickly be raised and clamped into position when the boat is to be used. A construction plan in detail was not available for this type, but its general characteristics are shown by the figure on Plate 76. Compactness of stowage and the suitability for nesting have been factors which have influenced appreciably the design of this type.

All boats were new, in the best of condition, and had been obtained direct from the makers.

In order to be of the most value a basis for comparison must be used which involves either size or capacity. The former was chosen, and all boats were of the 28-foot size.

The inclining experiments were carried out using two plumb-bobs (one at each end) about 5 feet long. Pig lead was used for the inclining weights, and readings were taken with the lead on the center line amidships, then to port, starboard and back to the center line. The boats were in all cases in absolutely quiet water, and several readings were taken for each position with an agreement which was entirely satisfactory (seldom over one per cent).

The worst case as far as stability is concerned is when the boats are loaded to their full complement, and that condition was simulated by loading the thwarts with sand bags (about 75 pounds each) so stowed that the center of gravity of each pair of sacks was at the proper height for a man sitting in that place. The height that this should be was determined by balancing a man fast to a plank in a sitting position and was found to be very close to 9 inches above the seat. Although two sacks averaged close to 150 pounds, the ballast was weighed each time it was put aboard in order to check the total weight. In most cases there were several persons in excess of the allowed load on board when investigating for the full load condition; but the resultant curves of stability, both statical and dynamical, have been corrected so they include only the number of persons that the inspection rules permit.

The derivation of the moments and areas of the sections for the many inclinations has been with the aid of mechanical integrators and the results have been plotted as curves. These curves have in turn been integrated to obtain the final moments and volumes. This was done because where the boat has quick changes of transverse form or when the rail goes under the area and moment curves are abruptly irregular and any numerical summation is apt to be seriously in error. A complete set of the curves for one of the larger angles of inclination is shown on Plate 79 to illustrate the method of arriving at the resultant curves of statical

and dynamical stability. The following table gives the characteristics of form, center of gravity, etc., of all the types used and Plate 78 gives the displacement curves and plots of all the hull functions:

Table of Characteristics of Form.

Conditions.	Met. rad. B. M.	Met. ht. G. M.	C. B. above base.	C. G. above base.	Metacenter above base.	Displacement. Lbs.	Draught above base.	Type.	Number.
Light.....	5.55′	4.29	.41	1.67	5.96	3,584	.72	Standard—Metallic.	1
Loaded...	3.58	1.39 2.04*	.86	3.05	4.44	10,559	1.56		
Light.....	5.69	4.05	.35	1.99	6.04	2,740	.56	Standard—Wooden.	2
Loaded...	3.54	1.09 1.52*	.86	3.31	4.40	9,784	1.44		
Light.....	11.31	9.21	.341	2.44	11.65	5,392	.56	Decked—Metallic.	3
Loaded...	5.67	3.10	.742	3.31	6.41	14,462	1.31		
Light.....	6.43	3.14	.497	3.79	6.93	8,840	.76	Collapsible—Wooden.	4
Loaded...	5.23	.67	.614	5.17	5.84	12,720	1.04		

*With load partly on bottom.

Plate 80 gives the curves of statical stability (in terms of righting moment) for the boats in the fully loaded condition (allowable load) except in the case of the collapsible, and the following table is derived therefrom:

Angle of inclination.	Righting moment in foot-pounds.			
	Standard metallic.	Standard wood.	Decked metallic.	Collapsible wood.
5°	1,300	1,080	4,780	Neg.
10°	2,500	2,030	8,350	Neg.
15°	3,620	2,820	10,980	Neg.
20°	4,550	3,440	3,180	Neg.
25°	5,300	3,910	910	Neg.
30°	5,900 0*	4,280	Neg.	Neg.
Angle of zero stability	30°	32°	28°	3°

*Curve drops from 5,900 to 0 at 30°.

The open boats, Plate 80, have a continually increasing righting moment until they reach such an angle that the rail goes under (30 degrees for the metallic and 32 degrees for the wooden) when the boat founders. The curves are normal and quite what one would expect, though it is of interest to note the very appreciable increase in stability which is caused by the seating of a portion of the passengers (15 in the metallic and 16 in the wooden) on the bottom of the boat instead of on the thwarts and seats provided for them. It is noticeable also that the wooden boat has less stability than the metallic though of the same external form. This was caused partly by the center of gravity of the boat itself being somewhat higher and partly by the fact that the thwart and seats were about one inch higher above the keel than in the metallic boat. The construction plans show no reason why the thwarts and seats should not be lowered appreciably and it would seem desirable to have them as low as possible.

For example, the wooden boat from the cross curves has an uncorrected righting arm, when loaded with 50 people and inclined at 30 degrees, of 0.90 foot. The distance of the center of gravity above the assumed axis of inclination is 11 inches, or 0.92 foot.

The correction for the righting arm is then $0.92 \times \sin 30$ degrees $= 0.46$ foot, and the corrected righting arm is $0.90 - 0.46 = 0.44$ foot.

Now if the thwarts were lowered 6 inches the resultant center of gravity would be lowered 0.35 foot in which case the correction would be $0.57 \times \sin 30$ degrees $= 0.28$ foot, and the corrected righting arm is $0.90 - 0.28 = 0.62$ foot, which is an increase in statical stability of about 40 per cent.

Probably the curves of dynamical stability on Plate 82 give the most comprehensive comparison of the merits of the different types from the stability viewpoint as they give the work done in foot-tons to incline the boats to the various angles. These were derived by integrating the curves of righting moments using one of the Institute's integraphs for the work. The following table is derived from these curves.

Table of Dynamical Stability—Load Condition.

Angle of inclination.	Work done in foot-tons to incline to angle.			
	Standard metallic.	Standard wood.	Decked metallic.	Collapsible wood.
5°	.024	.020	.105	....
10°	.100	.078	.390	....
15°	.230	.173	.785	....
20°	.395	.300	1,155	....
25°	.580	.443	1,230	....
30°	.800	.600	....	....

Dynamical Stability—Light Condition.

Angle of inclination.	Standard metallic.	Standard wood.	Decked metallic.	Collapsible wood.
5°	1,630	700	4,200	5,600
10°	3,000	1,350	6,600	6,000
15°	4,120	1,910	8,180	3,120
20°	5,120	2,400	9,140	610
30°	6,700	3,000	9,700	Neg.
40°	7,700	3,100	8,050	Neg.
50°	8,200	2,800	5,280	Neg.
60°	8,400	2,350	2,350	Neg.

Somewhat startling results were obtained with the collapsible boat. This was a new boat, obtained with the customary guarantee and was supposed to be in all respects ready for immediate service. It was of the dimensions given in the table and rated to carry 54 persons. When the inclining experiments in the light condition were made the boat did not come to a position of equilibrium after the inclining weights were moved to one side, as the plumb-bobs showed a slow but continually increasing angle, the reason being that water was slowly leaking into the pontoon. The boat was hauled out and a few days later re-launched, hoping that it had swelled tight; but with the same result. A position of equilibrium was eventually reached after several hours in the inclined position and the center of gravity determined.

When it came to the loaded condition the boat sank completely with 43 persons aboard, so that it was decided to accept for the load condition a less loading, one which would permit of the craft remaining afloat. Sixteen persons resulted in a freeboard of 1¼ inches to the top deck and this was the load used. The center of gravity for this and the light conditions are indicated in Plate 78 and the table. The curve of righting moments, when loaded with 16 persons, is shown on Plate 80 and it is interesting to note that the angle of vanishing stability is three degrees. The curve of dynamical stability is so small that it could not be shown on Plate 82.

The failure of this boat to live up to a higher percentage of its requirements was undoubtedly due to water leaking into the chamber between the decks and is an excellent illustration of what is bound to occur when water obtains access to the single buoyant compartment of a boat of this type. The essentially vicious feature is that while water leaking in entirely eliminates the craft's stability and seriously impairs its buoyancy, the leakage is unknown and cannot be bailed out as in an open boat. Moreover, any wooden construction subjected to the ordinary weathering and wear encountered on the decks of ocean-going vessels will not and cannot be expected to remain watertight. The bulwarks are not intended to be

watertight and the stability curve even when light has all the characteristics of that of a raft, with its quick-rising curve of righting moments for very small angles and reaching zero stability at an angle vastly less than the standard type of boat (see Plate 81).

In closing I wish to express our appreciation and thanks to the Welin Marine Equipment Company for their kindness in furnishing facilities for carrying out these tests.

Note.—Since the above article was written I have received a copy of the Report to the Secretary of Commerce of the Committee on Lifeboats, dated October 14, 1913, and it is of interest to note that it is their recommendation that "* * * collapsible boats or folding boats should not be allowed as any part of the required life-saving equipment."

DISCUSSION.

The Chairman:—Discussion is now in order on paper No. 5, "Stability of Lifeboats."

Professor C. H. Peabody, *Member of Council:*—The author of this paper is quite competent to present and defend his paper, but there are some statements which, perhaps, I can make to advantage. The investigation upon which this paper is based was assigned to two students of the Massachusetts Institute of Technology, upon which they were expected to base a thesis. Professor Everett was instructed to superintend the carrying out of the work. The responsibility for the condition of the boats at the time they were tried, the method of carrying out the work, and the writing of the paper, all belong to the author. There was no compensation received by any person who was interested in carrying on the work. After the work was finished, with the advice of myself, this paper was prepared and is presented before the Society.

The paper, further, I think wisely, does not undertake to designate the advantages of the several types of boats, except as indicated by the facts presented. There may be a considerable difference of opinion, and to show that this is not imaginary a member of the Society, not present, called my attention to the fact that in his opinion, while the wooden boat did not show up so well as the steel boat, it was preferable as a lifeboat and he gave good reasons for that.

It is not at all sure that the third boat which, in some ways, shows remarkable qualities, is the best boat. I may say that the designer of this boat has explained its properties to me at length and has communicated to me tests which have been made on the boat, and still I cannot be convinced that this type of decked lifeboat is the best one. It may seem a little venturesome for a landsman to express an opinion counter to that which is presented by an accomplished seaman who has had large experience in handling boats at sea. Perhaps I may justify myself, if the Society will allow me to do so, by stating that for more than ten years I was the Chairman of the Board of Lifesaving Appliances for the United States Lifesaving

Service, and had an opportunity of becoming acquainted with the boats used in that service and the men who handled them. If I may say briefly, there are in the service three types of boats. The open surf boat many people think can go anywhere and do anything that should be demanded of any boat rowed by oars. There is a decked lifeboat, with a bailing arrangement, which was developed for the service by an able officer of the Revenue Service, who has done more toward perfecting the appliances for lifesaving than any other individual. This boat is furnished to surfmen, as they desire, and as it seems expedient, is much in favor with them. Nevertheless, I believe there are grave questions whether it is a good boat for the purpose, which is distinctly different from that of boats carried on a ship. This boat must have water ballast in order to carry the crew. The crew and the passengers are all on the deck, and a deck load on any vessel is a very questionable matter.

I may state that in the course of my service I had occasion to make many experiments (something of the sort shown in the paper under discussion), and the impression which I received in regard to decked lifeboats has prejudiced me against any type of decked lifeboat, except the regulation lifeboat with high ends and heavy metal keel, a type which no one would think of carrying on ships.

I thought at the time when the paper was shown to me, before being offered to the Society, and I still think, that the paper does not declare the makes of the boats.

Coming home this fall I found upon the boat deck of the steamer a lot of boats of type similar to No. 4—I do not know the name but I think they are not the same boat. I was so impressed against the boats (which were lettered to carry the same number of passengers as the regulation boats under davits) that I made up my mind if I ever had an opportunity to use any influence against the carrying of boats of that type on a steamer I should do it without hesitation. I think it is quite important that every lifeboat should be competent to do everything that it purports to be able to do.

Mr. E. H. Rigg, *Member*:—I think the work which has been done recently on the subject of lifeboats is ample evidence of how greatly the whole world is interested in this question, and it is of good omen that so much work has been done. We have recently had a report from the British Departmental Committee on Boats and Davits, which goes along very similar lines to those of Professor Everett's paper. One paper confirms the other to a marked degree.

There is one point in Professor Everett's paper to which I would like to call attention. He emphasizes the desirability of getting the people seated as low as possible in the boat, and his curves give the stability for one-third of the complement seated on the bottom of the boat. There will be trouble in persuading people to sit on the bottom of a boat; an old sea dog will be glad to get down there out of the wind, but the general public will generally prefer to keep high up.

I have recently had something to do with the designing of a large lifeboat, twenty-eight feet long, to seat between fifty-five and sixty persons. Professor Everett mentions the desirability of lowering the seat. I do not think you can do much in that line, as the thwarts must be a certain distance below the gunwale to suit the oars, which will be needed in manipulating the boat. What we did was to arrange an auxiliary set of combined seats and stretchers at a lower level than the regular thwarts and side seats; the oarsman then gets a stretcher, the next thwart being too far away for proper reach in a good rowing position.

This arrangement automatically improves the stability, and provides more seating accommodation at the same time.

Professor Herbert C. Sadler, *Member of Council:*—I will draw attention to the point which I think is the most important one in this paper, and that is the importance of stability in lifeboats. That same fact has been brought out in connection with the report of the British Commission. It has always seemed to me if we are going to put a lifeboat on a ship it ought to be stable, at least under the conditions under which it is supposed to operate. This is brought out in the paper. If you will refer to the stability curves, particularly in connection with the decked lifeboat versus the standard metal or wood, the decked lifeboat is a foot wider and a foot shallower than the ordinary boat. The decked lifeboat has a much better stability curve.

I would like also to draw attention to one fact in connection with the steel versus the wooden boat. In my experience a good many of these fittings about a vessel do not get the attention, perhaps, that they ought to get, and metallic lifeboats are usually built of very thin metal. In salt water they are very liable to corrode unless especial care is taken of them. The wooden boat, although it may be slightly leaky, will probably stand up better under the general conditions of service, and a slight leak probably would not be very serious; but in the case of a boat built of light material and liable to corrode rapidly, we may have trouble with it. It has been argued that the metallic boat is fireproof. I think if a fire got up to a metallic lifeboat that it would not be of much greater use than the wooden one.

The conditions under which lifeboats are likely to operate to-day are very different from what they were some years ago. With the installation of wireless telegraphy, there is no necessity, except in some special cases, for lifeboats to take long trips. In fact, it is far better for the lifeboats to remain where they are, if the passengers have to take to them, and wait to be picked up; therefore we do not need to have anything very much in the shape of a good sea boat. It seems to me we want something that is very stable and will float and hold a lot of people. There is no necessity for much in the way of movement. There is one feature in the latest report of the British Commission which is very interesting, and that is a proposition to install a very large boat which is capable of holding, say, two hundred people or more. The boat is a decked boat, with the people inside, and I think that is quite worthy of consideration.

The Chairman:—Is there any other gentleman who desires to speak?

Mr. E. Sivard, *Member:*—What I desire to say is not in discussion of this paper but an addition to it which I would like to give. The experiments recently made in England have given results regarding the collapsible wooden lifeboat somewhat similar to the results at which Professor Everett has arrived. They have, therefore, on the other side evolved a somewhat different kind of a collapsible wooden lifeboat. I have just returned from Germany and I have there seen a number of boats of this new type. The change in the design is principally the substitution of copper tanks for the cork filling. That, of course, would be an improvement if the whole space underneath the deck were filled with copper tanks. The Board of Trade rules require one cubic foot tank capacity per person, and these German boats,

the Oltmann boat in particular—they are more or less of the same type, all of them—have only what the law requires, one cubic foot per person. The space underneath the deck in a deck lifeboat has to be about four cubic feet for each person to provide proper buoyancy and, therefore, if this kind of a boat, which is supposed to be superior to the old-style collapsible boat, should be punctured in launching or should leak, it immediately loses about seventy-five per cent of its buoyancy. There is no way of getting at the inside of this boat to stop the leak and, therefore, it seems to me that with this kind of a boat, which complies with the English rules for decked lifeboats, we are almost worse off than with the old collapsible boat with cork filling. The other type of boat referred to in Professor Everett's paper, the decked steel lifeboat, is arranged differently, with watertight bulkheads, so that a puncture in this case would mean a loss of about twelve per cent of the buoyancy.

Mr. A. A. Sawman:—I would like the privilege of addressing the meeting.

The Chairman:—We will hear you.

Mr. A. A. Sawman:—I thank you for the honor of receiving me, although I am not a member of the Society. I represent the Englehardt collapsible lifeboat. I cannot make speeches, but I have been honored by your permission to appear before you, and would ask if you will not give me an opportunity to disprove some of the statements which have been made about the boat. I only learned about the paper two days ago, and have had it in my hands only a few minutes. The tests conducted by the U. S. Navy, the Revenue Cutter Service and Steamboat Inspection Service show very different results from the test reported on this Englehardt boat. We were not invited to the test, and do not consider it professional, and think it is unfair, to hold a test under such conditions. We have furnished a great number of these boats here in New York, and if the boat is no good we are the first who want to know about it. I will ask the Society, as a favor, to appoint a committee—it may not be your practice to do so—a committee of three or four, to take out one of the Englehardt boats on one of the steamers coming in or going out of New York. We will have the boat tested, and find whether or not it is a competent boat. We have furnished two hundred of these boats in the last two years to the steamships running into New York. We will test this boat in any way you like. We will be represented, and I think we can prove that the figures given and the argument are not correct, condemning, so to speak, a boat which has held its own for over twelve years, has had a great deal of opposition to it, and still has held its own in every way. I ask you gentlemen to afford us the opportunity to disprove the paper, which opportunity we have not had, as I did not know of it until a couple of days ago. I thank you for your courtesy.

The Chairman:—This matter has been before the Council. Mr. Sawman made the same request through me to the Society, and I told him that the Society, as a body, did not make tests for anybody or for any purpose. It seemed to me, if he were not satisfied with the tests reported in the paper, the simplest way was for him to have some other tests made by a competent person, and to have that person present to the Society the result of the tests. I have not seen the names of any boats referred to in looking over the reports of the tests. Apparently one of the boats is of the kind made by the firm which this gentleman represents, and apparently it did not show up quite as well as the other boats in the tests. I need hardly

say that the standing of Professor Everett is so high that there cannot be any question as to the absolute fairness in intent in carrying out and making these tests.

Mr. F. L. DuBosque, *Member of Council:*—The question at issue seems to be the fact that the particular type of boat under discussion leaked and for that reason the boat was not satisfactory. Undoubtedly, the gentlemen who made this test must have made some observations of the amount of water that came into the boat. With data showing the amount there would be an opportunity of telling what effect the leaking had on the stability of the boat, and whether it was important or otherwise; in other words, I think it would be of value if the author of the paper would add to the discussion his observation of the amount of water in the boat at the time he made the experiment.

Mr. W. L. R. Emmet, *Member of Council:*—In my experience, comparative tests of commercial articles are, as a rule, unfair, because you can very seldom produce the conditions of practice, and I think they rarely form a proper part of the proceedings of a scientific society. Tests of materials and of scientific principles are part of scientific investigation. Comparative tests of all commercial articles seldom are. I think that the paper is somewhat objectionable from that standpoint.

The Chairman:—Is there any other gentleman who desires to be heard?
Professor Everett, do you desire to reply in the discussion to what has been said?

Professor Everett:—Yes.

The Chairman:—Now is the time.

Professor Everett:—Mr. Rigg's remarks about the desirability of seating the passengers low is directly in accordance with my suggestion, and in making the suggestion I was guided by the large gain which is obtained by slight lowering of the seats and thwarts. It would seem as though it might be structurally possible for those who are engaged in the business to arrange the seats for the passengers lower, and perhaps let the seat from which the oarsmen operate remain higher.

Professor Sadler speaks of a very large boat, but I presume that represents difficulties in connection with launching which I do not care to discuss.

The questions which involve the accuracy of the paper, and questions which involve the manner of making the tests, I think are pertinent questions, and I am glad, indeed, to answer them.

The tests were undertaken in the normal routine work which comes to the Institute. The work furnished material for theses for two members of the graduating class, and I can say definitely and with assurance that the boats were treated as nearly as possible alike in every case, the only favor which was shown—if you can call it that—was the favor given to boat No. 4, of hauling out and relaunching which I mention in the paper. The boats were all new and obtained through legitimate channels. The No. 4 boat, about which the discussion seems to concentrate, was bought from the builders direct. I have the builders' certificate guaranteeing that boat.

The work which was done was done entirely under my supervision, from start to finish, no commercial organization had anything to do with it other than the furnishing of the boats, and the reports were not transmitted to any organization or individual previous to this printed report which you see here.

Mr. DuBosque speaks of the leakage, and that is really the whole meat of the matter. Undoubtedly, if the boat had not leaked, she would have shown a better stability curve. There is no question about that. There are, however, two questions involved which are pertinent. One deals with the wooden construction, when subjected to normal wear and tear in sea service, and is:—Is it possible to make wooden construction so permanent that it will always remain watertight? A boat of this type must be absolutely watertight, otherwise there will be free water in the large, unsubdivided bottom compartment of the boat, and the moment you have free water in this lower pontoon it has a disastrous effect on the stability. Furthermore the leakage is unseen, is insidious in its action and cannot be controlled by bailing as in an open boat.

The other question is:—Was it fair to consider boat No. 4 as a boat representative of its type, and in a condition which it might reasonably experience in service, rather than as possibly an abnormal or a damaged boat? I thought carefully about this, and decided in the affirmative, because, as I have stated, the boat was new and was obtained through legitimate channels in the normal way; it was presumably entirely ready for service, and came to us in that condition. It was obtained several weeks previous to testing, and had not been tampered with in any form from the time it was purchased until it was tested. Perhaps a dominating fact in my decision that the craft was in a condition similar to what it might meet in service, was a statement which is made in the catalogue describing this boat, and which I will quote verbatim. It is as follows:

"A 20-foot boat, even when filled with water, will sustain over 4,000 pounds, a 26-foot boat, over 8,000 pounds (fifty-three persons) even with its sides torn, its plugs lost, its bottom crushed. * * * Its construction is such that it cannot capsize even if all the passengers it will hold are crowded against one rail."

With a statement of that sort it did not seem unfair to the boat to consider it, not an abnormal boat, but typical, and in a condition not unforeseen by the builders.

The Chairman:—The next order of business will be the reading of paper No. 12, entitled, "Change of Shape of Recent Colliers," by Naval Constructor Stuart Farrar Smith, U. S. N. In the absence of Mr. Smith, the Secretary will read the paper.

The Secretary read the paper.

CHANGE OF SHAPE OF RECENT COLLIERS.

By Naval Constructor Stuart Farrar Smith, U. S. N., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

That ships bend in the middle has, of course, been well known for generations; and the tendency of wooden ships to hog was so well known that their keels were laid to a curve, which it was judged from experience would be approximately straightened out after they were afloat. The old records of the Bureau of Construction and Repair contain much interesting information as to the allowance for hogging in the case of our old wooden sailing and steam vessels, as well as information as to the changes in shape due to launching and loading.

But with the introduction of iron and steel vessels, at first of short length and heavy scantlings, the changes in shape were so slight that they were practically neglected. At the same time, the importance of calculating the strength of these comparatively new structures was brought to the notice of designers, and the present strength diagram was developed. As the ships grew longer, it was apparent that weight could be saved if the superstructures were not built to resist the stresses arising in the upper part of the girder; hence arose the expansion joint in long deck houses on passenger steamers which has brought itself loudly to the attention of the unfortunate land-lubbers whose staterooms were near it.

It has, therefore, been known for many years that steel ships worked, but the subject of observing the amount of flexion and from that deducing the stresses to see how they compared with the results provided for as a result of the strength diagram, does not seem to have been investigated in proportion to its importance, or to the opportunities which exist for obtaining data.

The observations which are here presented to the Society are not as complete as they should be, and consequently only rough deductions can be made. This is partly because as the observations were made it appeared that additional data of different sorts should have been taken. In other words, hindsight was clearer than foresight, and if the observations were to be repeated a good deal more could be learned with very little additional trouble.

Crude as they are, it is hoped that the results may interest some of us enough to make similar observations in such form that strength calculations can be checked, and possibly our designs improved.

The loss of the Cobra and Viper in England led to an elaborate series of tests on one of the British destroyers. Observations more or less extensive have been made on several of our destroyers, and it is common practice to erect battens or take sights before launching so that any great change in shape when afloat can be ascer-

tained; but these observations have been based largely on the idea that a steel ship does not change much, and that if much change of shape occurs, something is wrong. It would probably surprise a good many owners to learn that a 500-foot ship can bend over 6 inches due to loading and be none the worse for it; also to know that a rise in temperature of only 7 degrees may change the shape by an inch.

The amount of change in shape in the keel line of battleships is another matter which is not as fully realized as it ought to be, especially in the case of the new ships with several turrets, and I hope that some one of the members of the Society who is in possession of the data, will take the trouble to give us the results found by comparing the alignment of turret roller paths afloat and in dry dock.

The observations shown on Tables 1, 2, and 3, Plates 83 and 84, were taken on the colliers built for the Navy by the Maryland Steel Company at Sparrow's Point, the Neptune, Orion and Jason. The last two were sister ships, built on what is generally known as the Isherwood System, while the first was similar but slightly longer and built with transverse framing.

The Neptune was the first ship built and shows considerably more change of shape than the two ships with longitudinal framing, having a maximum of 6½ inches against less than 5 inches for the Jason and only 3⅜ inches for the Orion. In this statement I omit the Jason's condition of April 3, 1913, as she was at that time damaged by a dynamite explosion on a vessel lying near her.

From these tables the curves shown on Plates 85, 86 and 87 have been plotted. I shall not attempt any detailed discussion of the data, as they speak for themselves, but a few points of general importance will be referred to.

The sister ships show surprisingly different results. The Orion showed considerable hogging immediately after launching, while the Jason, like the Neptune, remained nearly straight. Moreover, the Orion when loaded showed no sagging, but the point of maximum hogging simply moved aft somewhat as if her cargo had rolled her "hump" toward the stern. The Jason, on the other hand, behaved like the transverse-framed Neptune and changed from slight hogging when light to a considerable sag when loaded. The cause may lie in the difference in the tank tops, as I shall explain.

After the observations had been made on the Neptune, the question arose: "If a ship bends, that is, if the main deck is forced up or down, what happens to the bottom?" As a result of this, on the two later vessels sights were taken through openings left near the foot of each bulkhead in the cargo holds. Observations of the height of the sight line above tank tops are given on Tables 2 and 3, Plates 83 and 84, while corresponding curves are plotted on Plates 86 and 87; these show that the Orion's tank top was convex, while the Jason's was concave before launching. As all three of these vessels were built on the same ways, it is unlikely that the blocks settled so differently, and it is therefore probable that the curve in the tank top was due to slight structural unfairness. This initial convexity in the Orion, which remained even when loaded, would seem a desirable thing, as it apparently resulted in reducing considerably the maximum change of shape, and may have acted to a small extent after the manner of an arch.

Another point, although to be expected, is that none of these ships came back to their original shape when docked.

In connection with the tank top curves, it should be noted that while the deck of the Jason (Table 3, Plate 84) at Station No. 5 went up only 5-16 inch after launching, the tank top immediately below was forced up 1⅝ inches. On the Orion (Table 2, Plate 83), where there was an initial convexity of the tank top, it rose 13-16 inch, while the deck at Station No. 5 rose ¾ inch.

As originally planned on the Neptune, there were no stations for sights aft of the cargo holds. Just before completion it was decided to establish Stations Nos. 7 and 8, and readings were taken at the last two sets of observations, but as they did not materially alter the curve, these additional stations were omitted on the later vessels.

Of these colliers, only the Neptune had expansion joints in the track for handling coal fore and aft, and on her some observations were taken to make sure that the joints allowed sufficient play to relieve the track from undue longitudinal stress. The readings are given on Plate 85, and show that for an increase of sag of about 3 inches, there was no motion at all in the joints. The first set of readings was taken without reference to the question of change in shape of the hull, but as the ship was substantially in the same state on May 23 (see Table 1, Plate 83) as on June 14, it will be seen that in changing from maximum hog to maximum sag, practically no motion took place in the joints.

In the case of each of the three ships, the change in shape due to fitting out after launching is obscured by the rising temperature, which produced a hog; while the effect of the former is not clear, some light is thrown on this by the tank top curve in the case of the Orion, which shows that putting in the machinery reduced the hog of the tank top although, owing to much higher temperature, the hog of the upper deck had been considerably increased.

As regards change in shape due to temperature alone, none of the observations on either the Orion or the Jason afforded any good comparison. In the case of the latter, there are, it is true, two observations made at different times with the ship complete, but the conditions of loading, etc., as indicated by draughts, show that these cannot properly be compared with one another. This lack of ability to compare the temperature effects is the more regrettable as it was on these two ships that tank top readings were possible.

On the Neptune, however, two sets of readings were taken on the same day (Table 1, Plate 83) and under the same conditions of loading. The ship was very nearly complete, and if tank top readings had been possible, the results would have been even more valuable. These observations show that for a rise of temperature of 7° F. the maximum hogging increased 1 inch, while the two curves (Table 3, Plate 84) show that the effect was fairly uniform throughout the length of the vessel.

The method of taking sights was very simple. A transit instrument mounted on a special short-legged stand was placed on a breast hook at the stem head, its

center being located over a punch mark on the plate of the breast hook. The transit was sighted on a permanent target located at the after end of the deck house, and the heights were observed by a measuring rod held vertically on each of the hatch cover supports which were used as the observing stations.

Table 4, Plate 84, shows some observations made on the collier Nereus, built by the Newport News Shipbuilding and Dry Dock Company, and though the method of observing was somewhat different, and the resultant curves (Plate 88) were differently plotted, a comparison with the other vessels is interesting.

The Nereus is in general similar to the Orion and Jason, except that she is 10 feet shorter and is built with the ordinary transverse framing. No sights were taken before launching, but a line was run when the vessel was practically complete. A second set of sights was taken in dock, and on the assumption that she had straightened out, this latter set was then used as establishing the datum line; and the curves shown on Plate 88 were plotted for hog and sag, although in Table 4, Plate 84, all the readings were taken as sag.

In conclusion, I wish to express my obligations to Mr. T. M. Cornbrooks, Chief Engineer of the Marine Department of the Maryland Steel Company, as it is largely due to the interest in this matter taken by him and by his assistants that these observations were made.

DISCUSSION.

The Chairman:—Discussion on this paper, No. 12, "Change of Shape of Recent Colliers," is now in order.

Naval Constructor J. G. Tawresey, *Member:*—It has been my fortune to have had to do some work along the lines considered in this paper, and as I found a tendency in some quarters to regard it as a needless refinement, I am somewhat pleased to find the subject treated in this paper and brought before the Society. I wish that the author had gone on and shown us a way to get around the difficulties which he brings out in the paper.

It is true that vessels bend due to loading and due to other causes, and that the bending is a great deal more in some classes of vessels than in others. Colliers are mentioned in this paper. The vessels I had to deal with were torpedo-boat destroyers. Then we have car floats, floating dry-docks and other structures. I found on the destroyers, which were of less length than the colliers, quite as much change in shape as is reported in this paper. That change was found to be due to the loading, but the loading would not account entirely for it, and further investigation showed that there was a very considerable change due to differences in temperature. The change due to the difference in temperature was, for the range of observation made, two and sometimes three times as much as that due to the loading. The loading in a destroyer, you must remember, is the weight of her machinery and

the weight of fuel oil in the different tanks, and the weight of water distributed in certain ways, also the water in the trimming tanks to make up the loading to bring the vessel to some desired displacement. A destroyer consists of the machinery, loaded on the shell of the vessel, the deck over and a few thin bulkheads in between. She is much in the nature of a girder. The bottom flange of the girder is in the water, and must have practically the same temperature as the water; the upper flange is in the air, exposed to the heat of the sun. We were not very much surprised, when we took observations on a warm day, with the sun beating down on the deck, to find the destroyer hogged. The observations extended over a number of months, and when we did strike a really cold day we expected to find that the destroyer, with the same load, was sagged; but she still showed hogging, and to about the same extent. We then noted, that to protect the machinery and pipes from freezing, steam was on the vessel, the living quarters were heated throughout, the fire rooms and engine rooms were warm; we observed the temperatures of the deck plates, and found that the deck was much warmer than the water, and consequently the destroyer was still hogged. I was unable to construct any curve by which one could predict the hogging from the difference in temperature of the water and the upper deck. That was, no doubt, due in part to the effect of the loading, and in part to the method of observation not being sufficiently accurate to take account of very small changes.

In passing this part of the subject, it may be of interest to state that I made some investigations on a battleship, and did not find corresponding conditions. The battleship has a great many more decks, the deck that is heated from the machinery lies nearer the neutral axis of the girder, and as far as my observations went I did not find anything corresponding in a battleship to the changes in shape that take place due to changes in temperature on a destroyer.

My interest in the matter was not so much in the stresses and strains as in the effect on displacement. The contract trials of our destroyers are run at a displacement equal to the weight of the boat plus a certain specified loading. A number of the shipbuilders have constructed at one time two or more destroyers from the same plan. Some of these destroyers have run more than one trial, and it was a part of my duty to determine the weight of the vessel, the displacement and draught at which the trials should be run. It is no wonder that the builders commenced to ask questions when, only a few weeks apart, we would give them a very different displacement at which the trial should be run.

I may say that every care is taken to determine these displacements as accurately as possible. The draughts are all taken by internal draught gauges which, you probably know, consist of a glass tube with a proper sea connection and a needle valve to choke off the flow of water; precaution is taken to flush the gauge, to be certain that the temperatures of the water in the tube and in the pipes leading to it are as near as possible the temperature of the water outside. Instead of taking off the displacement from a small scale curve, we prepare a large diagram that gives the calculated displacement for each inch, and this allows us to interpolate and get the displacement very accurately for a fraction of an inch difference in draught. This displacement is checked with the reported weight, and it had been customary to take any difference between the displacement of the vessel, observed as accurately as possible, and the recorded weight, as an error in the recorded weight. In taking observations on a vessel, taking one or two early in the morning, and another observation later on the same day, when there was no appreciable change of the weight, and when allowance could be made for what weight had been carried on board or taken off, we would find the displacement say five tons

less than the recorded weight one time, and the next ten or fifteen tons greater, on a vessel of five hundred or six hundred tons displacement, at the time the observation was made. Consequently it was necessary to take up this question and to attempt to find some way of treating it.

The matter of loading is quite important to the shipbuilder in running trial trips. Every added ton adds appreciably to the horse-power necessary to be developed to secure the given speed. There is also another matter to which I will refer. On the trials, in loading the vessel for a run, it is necessary to take in water to get the vessel down to the required displacement. We took in five or ten tons of water in the trimming tanks to get the required draughts and the displacement, and then found that the displacement determined from the draught had increased ten or twenty tons.

The means adopted for the vessel to which I refer, to observe its change in shape, was to fit an additional internal draught gauge, as near central between the other two as practicable, which means a gauge fitted amidships. We then read accurately the draught shown by the three gauges, and took the difference between the readings of the middle gauge, and the mean of the other two, as giving the amount that the ship was hogged or sagged between the end gauges. A curve of correction for displacement was calculated and plotted to show the amount to be subtracted or added, in proportion to the difference in readings. Of course the ship might show the same difference in readings of the gauges at different times, and not have exactly the same displacement, that is to say, may not always be bent into exactly the same shape, between gauges. But if you stop to think of the long flat curve to which a vessel hogs or sags, it is evident that the correction, whether based on bending to a parabola, a circle or even a triangle, will give a more accurate result than to neglect the correction altogether. That is what we found; in a large number of these comparisons, there was never a time when the application of the correction did not bring the results of different observations nearer together and so that they were much more consistent with one another, and much nearer to the recorded weights.

Mr. E. H. Riggs, *Member:*—Mr. Tawresey has given us a very interesting description of the methods adopted on destroyers to find the amount of deflection and to allow for it in the displacement on trial and at other times. It has been my fortune, or misfortune, to have to get that displacement during the trial trips of some destroyers, to Mr. Tawresey's satisfaction, and we have had our fun in doing so. The midship draught gauge he refers to, in the destroyer, as you all know, must come in or near a fire room. In one case it came right in the fire room, and someone started to read it under air pressure; the result was startling. After that experience we did not read it when under air pressure. The value of the midship gauge in arriving at a correct light weight of the ship is indisputable.

In the discussion on Mr. Howard's paper, some reference was made to changes of shape in lake vessels. These colliers also are single deckers, and anyone who has had anything to do with keeping track of the weights, in connection with this type of vessel, will know at once the difficulties of the situation. As an instance of hogging that takes place, due to difference in temperature, I will cite a case which came to my attention—a carfloat, 330 feet long, lying at our wharf in the sun, with nothing on her at all. We tried to get a check on the weights, but found from the end draughts and displacement curve that they were not anywhere near what they should be. We noticed that the sun was hot and the water cool, so we then took a transit and shot a line, finding that there was a hog of eight

inches in what should have been a straight line. These deflections undoubtedly take place, and it is important that we should devise means to check them up. The midship gauge is of practical value in destroyer trial trips, where weight is particularly important; as Mr. Tawresey said, a slight increase of weight on a destroyer means a big increase of horse-power at 30 knots.

Naval Constructor J. H. Linnard, *Member:*—I think Mr. Smith's paper will call more generally to the attention of shipbuilders the great importance of this temperature question with reference to draughts and hogging and other phenomena that are exhibited under the influence of temperature. I have had some experiences in the past in that matter, and the one that particularly drew my attention to it occurred during the tests of a floating dry-dock that was built for the government some years ago and tested in Chesapeake Bay. The contract required that two very heavy ships, one of the short type of a battleship, and the other of the long cruiser type, should be docked in succession, and the deflection of the dock ascertained with the condition that certain maxima deflections were not to be exceeded. We found that our time was very limited, owing to the service of the ships, and the members of the Board of Civil Engineers who had established very exact lines for the ascertainment of these deflections were, of course, limited as to the times when they could take their observations, although they had established transits and sight stations in the most careful manner. On taking these observations, inexplicable deflections were observed, such as were quite different from what might have been expected from the loading of the dock by the ship. We devoted considerable thought to the matter, and we came to the conclusion, after some calculations, that it was probable that the temperature distortions, that is, the distortions due to temperature in the upper member of the floating dry-dock, subject to the hot sun, were greater than the deflections calculated from the known strength of the dock, due to the loading of the dock by the ship.

Mr. Francis B. Smith, *Member:*—We are very much interested in this subject of the hogging and sagging of ships in loading and carrying their load. Our company is going to a good deal of expense at the present time in making tests in connection with this matter, and I am interested in getting all the information I can. Our ships are long and flat, single deckers. They are pretty high for the dock we have to load from, loading iron and, as a consequence, we have to begin from the back end of the ship to load, and work forward as she goes down, as the ship is too high forward for the height of the spouts. We begin at the back end and take every other hatch as we work forward, the hatches are 12 feet centers, and when we do this we do not have any bad effects that is, we can load our ship pretty nearly in shape, but sometimes we put a little too much freight in midships, before we get clear forward, on account of the bow being so high for the spout. The boat gets sagged this way in the middle, and after she once gets a sag in there we cannot get it out by loading in the two ends forward and aft; she gets a permanent set there which cannot be taken out until she is unloaded, and we have to be very careful of that matter, to see we do not get this sag at all in being loaded. That is a point I would like to get all the information on that I can.

Professor Herbert C. Sadler, *Member of Council:*—I should like to ask the last speaker if he has actually measured the amount of sag in his vessels, and what he considers to

be the maximum permissible. It is, perhaps, generally known that the lake freighters have draught marks amidships as well as at each end. I think any information of that kind would be valuable, as to the maximum amount which has been observed in any case and its effect on the ship.

Mr. Smith:—We had a very serious case during the last season, where the ship, when loaded, had the same draught aft and midships, and drew a foot less forward, and it had quite a destructive effect on the hull of the ship and loosened up a great many rivets. Usually, we do not calculate to get more than two or three inches sag in the middle.

Mr. Francis T. Bowles, *Past President:*—I would suggest that the practical value of this paper would be much enhanced if either the author or Mr. Tawresey would add to their remarks an exact description of the most accurate method of laying off the draught marks on a vessel, and of correcting it when the vessel is loaded. I am aware that there are some tricks in both of these businesses. (Laughter.)

Naval Constructor T. G. Roberts, *Member* (Communicated):—I am glad the author of this paper has introduced the curves showing conditions on the Nereus, which were prepared under my direction at Newport News. I may also add that similar curves were previously prepared by me in the case of the collier Proteus, the results of which were quite similar to those shown for the Nereus. The Proteus being the first of these two vessels to be completed, I prepared these curves without any knowledge that similar data were being, or had been, taken in the case of the Sparrows Point colliers; and the purpose I had in view was to be able to account for an anticipated difference between the weights taken of the different parts prior to incorporation into the vessel, and the displacement as determined from the draught marks at completion. It struck me that the condition of bending actually found would be reasonable to expect, which the subsequent observations confirmed. I forget now how much the displacement was affected by the observed difference between the loaded condition under sag and the designed condition with keel flat as in dock, but I think it was something like 180 tons. Anyhow, it was an appreciable difference to account for when the weights and the displacement are being compared, or when the conditions at the trials are being met. Since the contract for the vessels required the work to be according to the best merchant practice, there was no provision for expenses to the Newport News Shipbuilding and Dry Dock Company and to Mr. William Gatewood for volunteering to supply the necessary facilities to enable this work to be conducted by the force of my office.

Admiral Richard M. Watt, *Vice-President:*—Merely as a matter of interest, I would ask attention to an experience of my own many years ago, when I was assistant to Admiral Bowles, at the Navy Yard, New York. He assigned me the task of hauling out seven torpedo-boats. They were small in size, and the longest, as I remember, was 160 feet. The vessels were hauled out on improvised ways, and I noted with some consternation on arriving at the yard one morning that the shores set up on the previous afternoon under the overhang forward on several of the vessels had dropped out during the night. This was very alarming, but, of course, the only thing to which this could be ascribed was temperature changes.

THE CHAIRMAN:—If there are no further speakers, we will consider the discussion closed, and the author of the paper will have an opportunity, if he desires, to make a written closure.

NAVAL CONSTRUCTOR S. F. SMITH (Communicated):—The members who have spoken in connection with this paper have brought out one of the points which I particularly hoped would be raised, and that is, that there is a great deal of information on this important subject available which could be compiled and submitted to the Society, without very much difficulty. I trust that some of them who may be in a position to make such compilation can be induced to undertake it.

As regards Naval Constructor Tawresey's wish that I had gone on and shown a way to get around the difficulties I mentioned, I would suggest that a great deal more information is necessary before we can do much in the way of suggesting remedies. In fact, it may be that remedies are not necessary and that these changes of shape are entirely harmless except in extreme cases.

The first observations were taken on the Neptune for the same reason that Mr. Tawresey found it necessary to make observations on the destroyers, that is, to be able to ascertain whether the vessel had been loaded for trial according to contract. It had been previously learned in the case of the Cyclops that there was considerable change of shape which necessarily raised the question as to what was the exact displacement of the vessel corresponding to the observed draught.

In view of the interesting remarks of Mr. Francis Smith, I trust he will at some future date give the Society the results of the tests he refers to.

There were a number of announcements made, after which the meeting adjourned for luncheon.

FOURTH SESSION.

FRIDAY, DECEMBER 12, 1913.

Vice-President McFarland called the meeting to order at 2.20 o'clock.

THE CHAIRMAN:—Before going on with the reading of the papers, let me say that the Council has held a meeting and passed on the applications for membership of three persons. The Council recommends the election of these gentlemen to the respective grades mentioned. The Secretary will announce the names of the applicants.

The Secretary announced the following names:—

Members (2)

Frederic R. Harris, Civil Engineer, U. S. Navy, Navy Yard, New York, N. Y.
James Montgomerie, Surveyor, Lloyd's Register, 17 Battery Place, New York, N. Y.

Junior (1)

Angel C. Hidalgo, Lieutenant, Ecuadorean Navy, P. O. Box 36, Philadelphia, Pa.

THE CHAIRMAN:—These applicants are recommended for election by the Council. You have heard the names. Those in favor of electing these gentlemen to the grades for which they have applied, and whose election is recommended by the Council, say Aye; opposed, No. These gentlemen are duly elected.

We will now go on with the reading of the papers, and we will take up paper No. 15, "Notes on Chain Cables," by Assistant Naval Constructor John E. Otterson, U. S. Navy.

Mr. Otterson then read the abstract of his paper, after which he said:—

"The history of large chain cables dates back a little more than a hundred years, and during that time but little advance has been made in the process of manufacture, so that the large bulk of the high-grade chain cable to-day is made exactly in the same manner as it was made here one hundred years ago, namely, by the hand process. That is largely due to the fact that the hand-made chain to-day is better than machine-made chains. In the manufacture of cables at present we have got to the limit of hand work, we have reached the limit of the size of cable which can be economically made by hand work, and as the size goes up it will be necessary to do a part or all of the operations of making chain cables by machines.

"Because of the fact that we are looking ahead to the manufacture of sizes of cable larger than three inches, experiments have been made at the Boston Yard to develop a machine process. I have made some sketches indicating the steps in the manufacture of chain links."

NOTES ON CHAIN CABLES.

By Assistant Naval Constructor John E. Otterson, U. S. N., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

ENGLISH CABLES.*

Ships' cables in ancient times were fashioned of hemp or roots of trees, and there is early mention of iron having been used in connection therewith, no doubt as rings or hooks spliced to the end of the hawser.

In 1634, Philip White, blacksmith, obtained a patent for mooring chains, which reads as follows:—

"A way for the Mooring of Shipps with Iron Chaynes by finding out the True Heating Ppareing and Temping of Iyron for the ppose and that he hath nowe attayhed to the True Use of the said Chaynes, and that the same will be for the great Saveing of Cordage and Safety of Shippes and will redound to the Good of our Common Wealth."

In 1690, Sir Cloudesley Shovel recommended that chain moorings be introduced into the English service, but no definite action was taken until more than one hundred years later.

In 1808, a chain cable was used on the Ann and Isabella of $221\frac{35}{94}$ tons, built at Berwick-on-Tweed. The chain was made by Robert Flinn, who is entitled to be known as the first maker of chain cables. The iron came from Wales, was of rectangular section, worked by hand hammer into links somewhat longer than present-day links and not fitted with studs. The cable was so successful that Flinn's business rapidly increased.

In 1808, Samuel Brown, Lieutenant, R. N., took out a patent covering the use of metal for ship's rigging and the use of short twisted links with swivels, and shifting shackles for chain cable. In 1800-1810, he sailed the Penelope, fitted with chain cables, 390 tons, to Martinique, Guadaloupe, and back. He reported so favorably on chain cables and labored so diligently to get them adopted in the Royal Navy, that before his death in 1852 they had come into general use.

In 1817, the Royal Navy decided to supply one and one-half chain cables to all sea-going ships of fifth-rates and upwards, and one to all sixth-rates and sloops.

In 1833, the first machine for testing cables was installed in the government yard at Woolwich.

By 1834, chain cables were in almost general use, * * *. At this time

*From "Chain and Chain Cables," Thos. W. Traill. Crosby, Lockwood & Co., 1885.

Lloyd's Register specified only the length of the cables; but modifications in the rules were considered, and eventually they were made to cover the strength and testing. About this time the underwriters ceased to charge a higher premium for vessels carrying iron cables, which action served to stimulate the trade in chain.

In 1840, links were for the first time side-welded. This practice grew among English chainmakers until now it is universal with them. Chain cables continued to grow in favor, and as their use extended, new plants were erected. Among these new plants was one at Runcam close by the canal. The chainmakers here were in the habit of depositing their burnt links in the canal, to the end that the canal barges finally grounded on them, which would indicate that the manufacturers' troubles in making chain are not entirely new.

In 1854, the cables of the British Navy were severely tried by a hurricane in the Black Sea. They withstood the test in splendid manner, whereas the cables of many merchant ships were parted, owing to their inferior quality. This brought to attention the necessity for more extensive and rigid tests. In 1862, Lloyd's Register made it compulsory for vessels to be supplied with chain cables which had been tested by a public machine and certified.

In 1864, an Act was passed regulating the proving and sale of chain cables and anchors, which Act was further amended in 1871. The requirements were strengthened from time to time, and as the chain improved in quality and reliability, confidence in it grew until its use was universal and the hempen cable entirely displaced.

It thus appears that present conditions are the result of a development extending over a period of about one hundred years, during which time progress was checked by the ancient prejudice in favor of hempen cables, by a natural conservatism on the part of builders, owners, and insurance companies, and by their failure to recognize the greater strength and reliability of the chain, due in no small part to lack of skill and honesty in manufacture, fostered by the lack of proper requirements as to strength and quality.

AMERICAN CABLES.*

The largest chain in this country of which there is record was made over 130 years ago when there was not a rolling mill or steam hammer in the country. Five hundred yards of this chain were made of 3½-inch square iron, with corners slightly rounded, each link weighing 275 pounds. A link of this chain is now in the possession of the Standard Chain Company, Pittsburgh, Pa., and shows a superior quality of iron and workmanship.

The chain was made for preventing the British ships ascending the upper Hudson, being buoyed on the surface by means of logs. The cost of this chain was $2,000.00 per ton, and it was made at Sterling, about 20 miles back of West

*References: "Chains and Chain Making." Paper before the Engineers' Society of Western Pennsylvania, Vol. 24, May, 1908, by James H. Baker, Forging Engineer.

Point. Seventeen forges were engaged in the work, ten for forging proper and seven for welding.

In spite of the excellence of this early product, there was little chain made in this country until about the middle of the 19th century. A ship's cable chain-works was established in Boston about 1835, and the Carr Chain Works was incorporated at Troy, N. Y., in 1865. About the same time, the works of A. Hewitt & Co. was established in Trenton, N. J., and the Hayden Chain Works at Columbus, Ohio. These early plants were vital factors in displacing the English chain then being supplied in this country.

Since that time, the industry has grown rapidly and has centered largely in the Pennsylvania district, where fuel and material are available.

FORM OF LINKS.

Many attempts have been made to develop special forms of links calculated to overcome the objection to the standard form now in use or to simplify or cheapen the process of manufacture. In spite of these attempts, the original form of link has held its own, and at present no serious attempt is being made to change it. The sketches herewith indicate the trend in this direction.

Figure 1, Plate 89, links made from two strips of half round, bent to shape, welded together on the flat side, with scarfs on opposite sides.

Figure 2, Plate 89, links made by winding flat strips of iron in form of ring, welding and working to proper cross-section between dies or rolls.

Figure 3, Plate 89, links made from bars rolled with enlarged section at points where re-enforcement is desired, *e. g.*, at the end of the link.

Figure 4, Plate 89, links made from bars rolled with projections designed to take place of stud.

Figure 5, Plate 89, links made from bars of special rolled section with center cut out as at E. Ends AA and BB bent around and welded together.

Figure 6, Plate 89, links made from bars of star section, from which joined links are cut by properly designed shears. Various types of weldless links made from wire bent or wound into special forms, one link intertwining with another.

All of these special forms have failed to displace the standard type, either because of impracticability or expense of the process, or failure to obtain benefits commensurate with the increased cost.

CHAIN LINKS MADE BY WINDING FLAT STRIPS.

The process indicated in Fig. 2 deserves special mention for the reason that it has been accepted to some extent in Germany, and a machine has been set up in this country.

The flat strips are taken from the furnace and pointed through the last link formed, and then wound in circular form as shown. This ring is then heated to a welding heat and passed between rollers on the forming machine which roll it into

a ring of circular cross-section. A flash is formed in this rolling process which is cut off by proper trimming dies in the forming machine. The ring is then dropped between linked-shaped dies which are closed upon it, pressing the ring into link-shape and at the same time setting the stud.

This machine has not been a success commercially for the following reasons:

(1) The process has not been accepted by Lloyd's, and much of the stud chain furnished in this country is to Lloyd's requirements.

(2) The machine is expensive in first cost and operation.

(3) When commercial firms attempt its use they are confronted by a strike of their chainmakers, who immediately tie up their shop by refusing to make repairs to chain, put in joiners, or to produce chain not required to be made on this machine.

The Government is probably the only agency that can establish this machine and process. The machine in this country is designed to make chain up to 2 inches, and a larger sized machine can be furnished to make chain up to 3½ inches. The 2-inch machine is not attractive to the Government, because of the small amount of chain of this and smaller sizes now used.

DISTRIBUTION OF STRESSES IN LINKS.*

TABLE OF SYMBOLS.

Q = One-half of load applied to chain.
Mb = Bending moment at any chosen section.
M = Bending moment inside of link at end of minor axis.
P = Normal force on any section of link.
S = Intensity of stress at any point of a cross-section.
ϕ = Angle between any section and major axis of link.
α = One-half of assumed arc of contact between adjacent links.
f = Area of cross-section of link.
d = Diameter of iron in the link.
r = General symbol for radius of curvature.
y = Distance of fiber from the center line.
$z = \frac{1}{f}\int \frac{y}{r+y} df.$

METHOD OF ANALYSIS.

The complete analysis may be found in the treatise referred to. The following is merely a brief outline showing the method of attacking the problem. Consider one quadrant of the link shown in Fig. 7, Plate 90. Denoting by $2Q$ the load on the link, the section at A lying along the minor axis will be subject to a normal

*From "Strength of Chain Links," by G. G. Goodenough and L. E. Moore, University of Illinois, Bulletin No. 18, September 2, 1907.

force Q. There will also be at this section a bending moment M, which can be determined from the equation:

$$M = Qd\left[\frac{\frac{1}{z_1}\left(1-\cos\alpha\right)+\frac{1}{z_2}\cos\alpha-\alpha\frac{b}{a}\left(1+\frac{1}{z_1}\right)-\left(1+\frac{1}{z_2}\right)\left(\frac{\pi}{2}-\alpha\right)}{\alpha\left(1+\frac{1}{z_1}\right)+\frac{d}{r}\left(1+\frac{1}{z_2}\right)\left(\frac{\pi}{2}-\alpha\right)}\right].$$

Now, consider any other normal section, as C, and consider the part of the link between sections A and C a free body. At C, let two forces, each equal to Q, but opposite in sense, be added to the system. One of these forces with the force Q at section A forms a couple whose moment is Qh; the other force is resolved into components, one $Q \cos \phi$ along the section; the other $Q \sin \phi$ normal to the section. The component $Q \cos \phi$ produces shearing stress and is neglected. At the section C we have, therefore:

A normal force $P = Q \sin \phi$.

A bending moment $Mb = Qh + M$.

With P and Mb known, the intensity of stress at any fiber is determined from the equation:

$$S = \frac{P}{f} + \frac{Mb}{fr} + \frac{Mb}{zfr} \times \frac{y}{r+y}$$

or less exactly but more simply from:

$$S = \frac{P}{f} + \frac{My}{I}.$$

Table of Distribution of Stress in Open Link.

ϕ	Normal force P.	Moment Mb.	Stress at center of section $y=0$.	Stress in outer fiber $y=+1/2d$.	Stress in inner fiber $y=-1/2d$.
0°.....	0.225Q	+0.671Q	+0.896Q/f	+4.012Q/f	−8.453Q/f
10°.....	0.257	+0.639	0.869	+3.863	−8.006
20°.....	0.352	+0.544	0.986	+3.420	−6.677
30°.....	0.500	+0.371	0.774	+2.785	−3.601
40°.....	0.643	+0.178	0.774	+1.739	−1.325
50°.....	0.766	+0.011	0.774	+0.836	−0.640
60°.....	0.866	−0.124	0.774	+0.104	+2.234
70°.....	0.940	−0.223	0.808	−0.504	+3.225
80°.....	0.985	−0.284	0.843	−0.917	+3.777
90°.....	1.000	−0.318	0.936	−1.366	+3.751
End of short axis..	1.000	−0.318	1.000	−1.546	+3.546

Fig. 8, Plate 90, shows a better idea of the distribution of stress through the link. At section a, lying along the minor axis, the inner fiber is subjected to a tensile stress of $3.55\frac{Q}{f}$, while the outer fiber is under a compression $1.55\frac{Q}{f}$. At section b, the tensile stress at the inner fiber is a little greater, due entirely to the curvature at that section, and at section c this tensile stress is still greater, because of the sharper curvature, notwithstanding the fact that the moment Mb is smaller. From here on, however, the tensile stress on the inside of the line rapidly decreases and reaches zero at the point L. At section e the moment Mb changes sign by passing through the value zero; hence at this section the stress is uniformly distributed and equal to $\frac{P}{f}$. From L to C the minor fiber of the link is in compression, the intensity of the compression reaching its maximum value $8.453\frac{Q}{f}$ at the point C. From A to K the outer fiber of the link is compressed, but from K to D it is in tension, the maximum intensity of the tension reaching the value $4.012\frac{Q}{f}$ at the point D. The lines HK and LM indicate the points of the link at which the stress is zero.

It will be observed that there are two points of maximum tensile stress; one at D on the outside, the other at E on the inside of the link. The compressive stress in the outer fibers is small, but at the point C it is very large.

The following table gives the stresses in the same link when provided with a stud; and Fig. 9, Plate 90, shows the distribution of stress in such a link.

Table of Distributing of Stress in Stud Link.

ϕ	Normal force P.	Moment Mb.	Stress at axis $y=0$.	Stress in outer fiber $y=+1/2d$.	Stress in inner fiber $y=-1/2d$.
0°.....	+0.555Q	+0.401Q	0.955Q/f	+2.814Q/f	—4.623Q/f
10°.....	+0.582	+0.373	0.955	+2.689	—4.246
20°.....	+0.662	+0.293	0.955	+2.314	—3.123
30°.....	+0.782	+0.152	0.895	+1.722	—0.905
40°.....	+0.892	+0.003	0.895	+0.913	+0.855
50°.....	+0.975	—0.109	0.895	+0.304	+2.180
60°.....	+1.029	—0.181	0.895	—0.089	+3.034
70°.....	+1.051	—0.211	0.895	—0.251	+3.216
80°.....	+1.041	—0.198	0.895	—0.180	+3.186
90°.....	+1.000	—0.056	0.989	+0.587	+1.480
End of short axis....	+1.000	+0.107	1.000	+1.858	+1.424

It will be observed that in this case there are two sections at which the bending moment is zero. The tensile stress reaches a maximum for the outer fiber at D, and for the inner fiber at about the point E. The compression is greatest at point C, but is only a little over one-half that at C in the case of the open link. The tensile stresses are also somewhat smaller than for the open link.

EFFECT OF STUD.

The effect of the stud upon the distribution of stress is to reduce the maximum tensile stress about 20 per cent and the heavy compressive stress at C about 50 per cent. The conclusion is then that if the stresses are kept within the elastic limit, the stud increases the strength.

The experiments of Committee D of the United States Board, Commander L. A. Beardslee, Chairman, appointed to test iron, steel and other metals (Executive Document No. 98—House of Representatives, 45th Congress, Second Session) indicate that when the link is stressed beyond the elastic limit the effect of the stud is to weaken the link.

This may be explained theoretically by the fact that as the link is deformed the width of the open link is decreased, whereas the width of the stud link remains the same. The effect of the reduction in width of the link is to reduce the bending moment and stresses within the link.

I am of the opinion that this rule cannot be applied without reservation to all lengths and forms of links and to all kinds of iron. In the case of the 3-inch close link chain manufactured for the Panama Canal lock gates, they tested to about 485,000 lbs. breaking stress, whereas the 3-inch stud link chain pulls to at least 525,000 lbs. It would appear that the deformation in the close link chain, due to closing in of the sides, bending the crown and quarters of the link closely about the adjoining link, strains the material more than in the case of the stud link chain. It is entirely possible that the effect of this greater deformation on the breaking stress would be different with a soft, ductile iron than with a hard, brittle iron. The manner in which the close link and stud link chain deforms is shown in Figs. 10 and 11, Plate 91, respectively.

We are concerned, however, more particularly with the strength of the chain within the elastic limit, and within this limit there appears no question of the superiority of stud link chain. The latter has the further advantages, that it does not foul so readily and offers greater structural strength for the resistance of cross-stresses and blows tending to deform or rupture it by forces other than those of pure tension.

END WELD VERSUS SIDE WELD.

An examination of the table and diagram (Fig. 9, Plate 90) of stresses in stud links indicates that theoretically the section at the end of the minor axis is subject to less severe stresses than is the section at the end of the major axis.

With a weld on the side the stresses over the weld are resisted solely by the

strength of the weld, the forces acting in a direct manner to part the welded surfaces. With a weld on the end the stresses over the weld are resisted by the strength of the weld, assisted by the form of the link, so that fracture along the weld can only take place by parting the weld and deforming the link at this point. The strength of form of the link at this point is nearly equal to the proof stress to which the chain is subjected.

The effect of working and heating the link in the vicinity of the weld is to make it dense and hard at this point, decreasing its ductility. With a side-welded link this will result in the side opposite the weld stretching more readily than the welded side, thus bringing heavier stresses on the welded side, resulting in non-uniform deformation and earlier breaks. With the end weld the change in structure of the welded portion does not upset the balance of stresses nor result in such non-uniform deformation, as the welded end is not required to act in exactly the same manner as the opposite end. The effect should be greater and more uniform strength.

This advantage of the end weld would be overcome to a certain extent by heat treatment, designed to remove internal stresses and re-establish the original structure of the iron and make it again uniform.

Aside from the preceding it is largely a question of where the weld can be most easily and surely made.

A good weld depends on:

(1) Properly formed scarf.

(2) Proper heat.

(3) Proper working.

As regards the scarf, the two methods are equal, in that the scarf is as easily formed in one case as in the other.

The side-welded link is more difficult to heat, as may be readily imagined, since it is harder to insert the side of the link than the end of the link in the fire, and the adjoining link interferes more seriously in the case of the side weld.

The side weld is somewhat more easily worked than the end weld, owing to the straight form of the link at the point where the weld is made. This advantage is somewhat overcome by the fact that the side weld requires two operations. The weld is made on one side of the link over one-half the breadth of the scarf, the link re-heated, turned and welded on the other side. The end weld is made with one operation and one heat. This difference is due to the difference in ease of heating and in the form of the tools necessary to make the weld. It would appear that this double working introduces greater possibility of dirt being enclosed at the weld and of the centers not being welded.

The advantages of the end weld become more marked when the weld is made in dies, as the end may be more easily inserted in dies than the side, and the adjoining link being slipped down to the end of the link opposite the weld does not interfere with the action of the dies. So it is that all machine-welded chain is welded on the end.

The English practice is to weld heavy chain on the side by hand, on the grounds

of greater accessibility and ease of working, but it is noted in the case of 4½-inch English chain made under the steam hammer, the dies are for end welding.

I am of the opinion that with the increasing size of our chain and the evident necessity of developing a power process involving die welding under a hammer, the end weld will be more easily and successfully made and in all respects superior to the side weld.

The advantages of the end weld over the side weld would therefore appear to be—

(1) Greater uniformity in distribution of stresses and in deformation.
(2) Form of link assists the weld to resist parting stresses.
(3) Greater facility in heating.
(4) Greater facility in working in dies.

PROCESS OF MAKING CHAIN.

A great number of patents have been taken out covering the manufacture of chain or some operation incident thereto. Such patents have been successful commercially only in so far as they have been applied to chain of smaller sizes up to 1¼ inches, and to chain of inferior quality. Chain larger than 1¼ innches and high-grade chain are to-day made, for the most part, by a hand process.

In the case of large hand-made side-welded chain, the links have been quite successfully bent by machine, but in the case of end-welded chain, even this has not been accomplished. The side-welded link is much easier to form or bend than the end-welded link, as the bends come further from the end, and so there is a longer leverage to work with. In spite of this advantage, the end weld is considered preferable for reasons already stated, which have to do with ease and certainty of welding.

In order that work involved in making chain may be fully understood, a description is here given of the process followed by the "hand" chainmaker on 3-inch chain.

The bolt is about 37 inches long and weighs about 78 pounds. It is furnished the chainmaker cold and straight with both ends sheared square. He places it in a coke fire and brings it up to a working heat. As his fire is not large enough to heat the whole bolt, it is necessary for him to heat one end at a time and turn it end for end until the whole bolt is heated with the hottest point at the center. This requires about 14 minutes, and the material is somewhat damaged by oxidation as the ends are exposed to the air upon being turned. A photograph of the fire with bolt in it is shown in Fig. 12, Plate 92.

The bolt is then bent into a "U" shape about a mandrel by means of the capstan bar arrangement shown in Fig. 13, Plate 91. The work is done by the chainmaker's helpers, as shown in Fig. 14, Plate 92.

On the same heat, the ends are thrown in slightly by hammering over the edge of the anvil, as shown in Fig. 15, Plate 93. This work, including bending, requires about two minutes. The bolt is then re-heated for scarfing, requiring

about three minutes, and the scarfs made by hammering down the end of the bolt with the peen of the hammer, requiring two minutes. The form of the scarf and the shape of the link, upon completion of this operation, are shown in Fig. 16, Plate 94. The link is then re-heated for final closing in preparatory to making the weld, the heating requiring three minutes, and the work one minute. The welding heat is then taken, requiring two minutes, and the weld is then made, requiring two minutes. The bolt is then re-heated for setting the stud. This heat is not actually required, and the stud should be set with the heat remaining after the weld is made, but the chainmakers are in the habit of taking the additional heat in order to make the work of setting the stud easier. The stud is set by turning the link on its side, and striking so as to close it in, as shown in Fig. 17, Plate 95. This operation requires the heaviest blows struck in making the chain link.

The making of chain should be considered under the following heads:

1.—Heating.
2.—Forming.
3.—Scarfing.
4.—Welding.
5.—Setting the stud.
6.—Handling the chain.
7.—Heat treatment.
8.—Tests.
9.—Arrangement of plant.

Heating.—Machine-made chain is heated in oil or gas forges with a number of openings in the top, through which the links are suspended from hooks. As one link is taken out another is put in to take its place, so that there is always a link ready for welding and no time is wasted between links. In some cases the chainmaker manages his own fire, while in others he has a boy to keep his fire "busy." In any case there is not much time lost and little waste motion. The work of these men is a delight to watch.

Practically all hand-made chain is heated in coke fires. The pre-heating for forming is done in the same fire as the heating for welding. This means that upon completing each link the chainmaker and his gang must wait for the next to heat. In the case of 3-inch chain this means about twelve to fourteen minutes wasted on each link. This time can be saved by installing a central oil-fired pre-heating furnace capable of heating a number of bolts to about 1,700° F. The number of bolts to be heated depends upon the number and output of the chain gangs. The design of such a furnace presents no special difficulties, and any of the usual types of oil furnaces of proper size will serve.

With such provision the chainmaker's fire becomes a welding fire solely. There has been some question as to whether welding heats on wrought iron can be obtained in an oil fire as reliably as in a coke fire. Old chainmakers and foremen favor the coke fire, and are skeptical as regards the oil fire.

Considerable experimenting along this line has been done at the Boston Navy Yard, and as a result of this I am convinced that satisfactory welds can be made with the oil fire, and believe that in the end it will prove more satisfactory than the coke because of the absence of dirt likely to foul the weld, closer control, more

uniform operation, greater ease in handling work around it, and less care and attendance.

An interesting point was brought out in connection with such oil welding fires in the course of the experiments conducted at Boston. The first fire was of the form shown in Fig. 18, Plate 96, the link being suspended through the opening in the top and hanging down into the chamber of the furnace. It was found that in spite of careful attendance the link would burn away and be badly scored or otherwise damaged. A heating chamber was constructed on top of the forge, as shown in Fig. 18A, Plate 96, and the link raised to the height of this chamber. No further trouble was experienced, and heats were readily obtained.

The explanation seems to be that in the first design the link was hanging into the combustion chamber, where there was present free oxygen in excess of that required for the combustion of the oil with the result that this oxygen combined with the incandescent iron and served for its combustion, the chemical condition being much the same as found in the oxy-acetylene cutting flame. When the upper chamber was constructed it became a heating chamber, and the lower one was devoted to the combustion of the oil. The combustion being complete when the flame struck the link, no oxidation of the iron took place. It is only necessary to see that the fire is kept "fat" by giving it enough oil.

The following table compares the breaking stress of five doublets heated in oil fire and five doublets heated in coke fire, all formed and welded by hand, and of 3-inch iron:

Oil Fire.		*Location of Break.*
532,940 lbs.		W_a—Across weld.
544,240 "		Q_w—Welded quarter.
532,100 "		Q_w—Welded quarter.
530,220 "		Q_w—Welded quarter.
504,448 "		W_c—With and across weld.
2,643,940 "		
528,796 "	Average.	

Coke Fire.		*Location of Break.*
572,560 lbs.		Q_w—Welded quarter.
538,640 "		Q_w—Welded quarter.
507,320 "		W_c—With and across weld.
568,940 "		W_a—Across weld.
519,320 "		C_w—Pulled out welded crown.
2,706,780 "		
541,356 "	Average.	

The advantage in favor of the coke fire is slight and easily offset by the fact that the work was all done by chainmakers accustomed to a coke fire, who had

never worked at an oil fire. They further had at their coke fire facilities that they were accustomed to and used every day, whereas at the oil fire they were in a strange shop with facilities to which they were not accustomed, particularly in the matter of handling the links from the fire to the anvil, which was done by means of the traveling crane. A good weld depends largely upon the time between leaving the fire and striking the first blow, as oxidation is going on all the time and heat being lost.

The effect of this is shown to a more marked degree in the following table, showing a comparison of coke- and oil-welded, machine-formed and scarfed links:

Oil Fire.		*Location of Break.*
568,160 lbs.		C_w—Pulled out welded crown.
459,780 "		W_c—With and across weld.
492,460 "		W_c—With and across weld.
532,960 "		W_c—With and across weld.
472,440 "		C_w—Pulled out welded crown.
2,525,800 "		
505,160 "	Average.	

Coke Fire.		*Location of Break.*
545,240 lbs.		Q_o—Quarter opposite weld.
556,160 "		C_o—Pulled crown opposite weld.
570,440 "		W_a—Across weld.
571,540 "		Q_o—Quarter opposite weld.
569,580 "		W_c—With and across weld.
2,812,960 "		
562,592 "	Average.	

The first break in the oil fire is 568,160 pounds, and this doublet was made with the regular operator in charge of the crane, who was able to move the crane out and down at the same time and so get the link on the anvil promptly. The other breaks are low and were made with an inexperienced operator in charge of the crane, who was able to move the crane in but one direction at a time, and so was slow in getting the link on the anvil. This difference in rapidity of handling appears entirely responsible for the difference in results.

Forming.—In the description of hand-made chain above, the method now employed for forming the links was outlined. In the case of the "machine-made" chain, the links are formed by winding cold on the mandrel, very much as springs are wound (see Fig. 19, Plate 97). The links are then cut from the spiral coil thus formed by shearing each turn of the coil diagonally along the line of the scarf (see Fig. 19A, Plate 97), the shearing blade operating also to open the link sufficient to permit of its being rove into the chain. This process bruises the material

badly, and subjects it to internal stresses incident to the cold working and damages it in general to an extent that could not be permitted in high-grade chain. Moreover, the process cannot be applied to sizes above 1¼ inches.

Numerous patent machines have been devised to form chain links of large size, all of which are open to some objection. Descriptions of these machines may be obtained from the Patent Office.

Side-welded links are more easily formed than end-welded links, as the long ends to be thrown together furnish ample leverage for accomplishing this, whereas with the end-welded links the ends are so short that the force applied must be so great as to crush the material while bending it.

A machine for forming side-welded links by winding on a rotating mandrel is in successful operation at the Bradlee Chain Works, Philadelphia, Pa., and at the Lebanon Chain Works, Lebanon, Pa. A machine of this type was purchased some years ago by the Boston Navy Yard, and is now installed in the chain shop at that yard. Experiments were made with a view to adapting it to the winding of end-welded links, and a mandrel was designed for this purpose. This experiment was partly successful, but not entirely so, for the reason that the short ends were not thrown in as far as desired, and the link was somewhat bruised and drawn at the quarters, the scarf curled up and made somewhat concave.

The general objection to all present end-weld link-forming machines is that they damage the bolt by bruising it at some point, or by drawing away the material in such manner as to reduce the section (this is shown in Fig. 20, Plate 96). It became apparent, therefore, that rather than try to bend the short ends of the link, it would be better to form them by a forging process whereby the end of the link, being forced into a die, might be given any form that is desired, even to the extent of reinforcing rather than weakening the link at the quarters.

This was finally accomplished in the Ajax upsetting machine in the manner shown in Figs. 21, 21A, Plate 98, the operation requiring one heat and one stroke of the machine for each end of the link.

Scarfing.—The process for forming the end of the link should further provide for the proper forming of the scarf. This is a matter of most serious consideration, in that it affects the quality of the weld. As shown in Fig. 16, Plate 94, the scarf as formed by the hand process is hollow, so that when the two scarfs are brought together a pocket is formed in the center, which tends to collect slag and dirt, and to prevent the surfaces of the scarfs coming together at the center of the link (see Fig. 22, Plate 99). It thus happens that many of our links fail by parting in the weld, showing the improper contact at this point. A desirable form of scarf is shown in Fig. 22A, Plate 99. It should be noted that the surfaces of this scarf are convex rather than concave, so that the first contact in the beginning of the weld is made in the center of the bolt in such a manner as to force the slag and dirt outward as the weld is worked toward the surface. Furthermore, the edges of the scarf are somewhat rounded in order to prevent their burning away or growing cool too rapidly, as occurs with a sharp-edged scarf such as formed by shearing or by sawing.

A scarf of desirable form was finally obtained by further forging the ends of the bolt under a drop hammer with dies, as shown in Fig. 23, Plate 100. The bolt as it comes from these dies is shown in Fig. 23A, Plate 100. This work is accomplished in the same heat as used for upsetting and bending the ends. The ends are now of the proper form, and if thrown together may be placed in welding dies without working and will give a link of correct form.

The scores in the upper die and the ridges formed thereby on the scarf are for the purpose of assisting the weld. As some difficulty was experienced in obtaining good welds, it was thought possible that the upsetting and scarfing operations increased the density of the material in the ends, made it hard and difficult to weld and further that the chilling effect of the scarfing dies produced a hard surface or case over the scarf which the heat could not penetrate nor soften. The scores were placed in the die to break up the hard surface and destroy the continuity of the surface fibers. The effect has been to produce better welds.

The ends of the link having been formed with slight reinforcement at the quarters and with convex scarf, it is now necessary to provide for closing the two ends together and reeving into the previous link.

This was first attempted by winding the link on a spiral mandrel, leaving an opening between the scarfs sufficient to permit of reeving into the previous link. This method was open to the objection that the link was twisted out of plane and was difficult to restore to proper form; and, further, that in winding, the link twisted about the longitudinal axis of the bolt and threw the scarfs out of parallel. As this did not always occur to the same extent it was difficult to allow for.

The method finally adopted was to reeve through the previous link and then wind on a flat mandrel slotted out to accommodate the previous link as shown in Figs. 24, 25, Plate 101. Figure 26, Plate 102, shows the winding completed and the scarfs laid together. The increased thickness through the portion to be welded should be noted. This experimental winding machine was designed to operate by hand so that it could be moved from place to place in connection with experiments performed in the vicinity of fixed machines. As a final proposition it would, of course, be designed to operate by power.

Welding.—With machine-welded chain the welds are made in dies under a hammer, usually a helve hammer. Two forms are used:

(1) The helve hammer with the trunnions about on the level of the anvil, striking a blow directly down, actuated by a cam, and employing a cup die. This type is very fast in operation and is used on the cheapest work.

(2) The helve hammer with the trunnions below the level of the anvil, striking a blow with a slight forward movement, actuated by a slotted lever from a crankshaft overhead, lifting the hammer against the tension of a spring and employing a die which is the reverse of the cup die, in that the cup die is on top and the pin die on the bottom, the cross-section being as shown in Fig. 27, Plate 99. This is known as the Standish hammer and die and is the favorite type among machine chainmakers, being a little slower than type 1, but making a better quality of chain. A photograph of this type is shown in Fig. 28, Plate 102.

Electric welding is practiced commercially on small chain up to ½ inch, the Standard Chain Company having quite a large plant. It is extremely rapid and cheap, but the material is somewhat damaged in the vicinity of the weld, due to the very high local heat, which tends to burn the iron and to set up internal stresses. This latter defect is somewhat lessened by working under a hammer or annealing subsequent to welding. However, the process is generally considered to be not capable of extension to larger sizes of chain, because of the uncertainty of the results. Aside from this it can well be imagined that the design of a suitable electric welding machine for 3-inch chain would be a very difficult undertaking in that the ends to be welded will require to be squeezed together so as to upset them slightly when the heat is taken, which operation will require considerable force with a cold link.

Press welds have been tried from time to time. So far as I know the welds made thus far have not been successful and have not stood the required tests, but I have been informed that the fault was with the heat and not with the press. However, it is the general opinion among experienced smiths that a weld should be hammered and not pressed. This seems reasonable, because of the more rapid action of the hammer, of the tendency of the blow to expel the dirt and slag and of the press action to confine it. It is possible, too, that the kneading effect of the light hammer blows rapidly repeated is to produce a finer structure and better arrangement of crystals. Considered as a shop equipment proposition the press will cost about $10,000 to install and this represents a rather heavy overhead charge for a chain fire. It would seem, therefore, that the hammer can be accepted as preferable to the press.

The selection of a power hammer for the welding of large chain links is difficult, and before a decision can be reached in this matter, it is necessary to consider the various types.

A helve hammer of the Standish type would, no doubt, prove excellent, but as this hammer is not made commercially in large sizes, a special hammer would require to be built.

It is maintained by experienced smiths and chain workers that a weld should be made with a type of hammer that will give an elastic blow and a succession of light repeated blows rather than a few heavy blows. In other words, the idea is to approach as nearly as possible to the kind of blows struck by a hand sledge.

The Bradlee hammer with rubber-cushioned helve most nearly meets these requirements. Considerable experimenting has been done with this type of hammer at the Boston Navy Yard, and some very satisfactory results obtained. These experiments provided for a double set of dies, one set of the cup form for starting the weld, and the other merely a horn projecting from the side of the anvil similar to that used by hand chainmakers. The objections to this type of hammer were that it required considerable working and moving of the link, that its form prevented the men working around it, and that its rapid action was difficult to control, and its stroke was so short that it gave scarcely room enough to enter the link into the dies.

In order to avoid these objections it was decided to attempt welding under a steam hammer. As the steam hammer has been used in England for the welding of large sizes of chain, there appeared to be sufficient reason for attempting this.

The experiments have shown, that its use greatly simplifies the welding of chain and reduces the hand labor to a minimum. There is still some doubt, however, as to whether it will produce satisfactory welds, and upon the experiments to date the conclusion must be that it will not. There are so many interlocking conditions, however, that the difficulty cannot definitely be charged to the hammer. The experiments are being made at the present time to determine this point definitely. The form of dies used in this connection is shown in Figs. 29 and 30, Plate 103. "A" is the impression in the die for welding, and "B" is a backstop for preventing the link from backing out of the welding dies and for supporting the link being welded and the weight of the previous link, thus relieving the chainmaker. The manner in which the link being welded rests in the dies is shown in Fig. 30.

Setting the Stud.—This operation requires the heaviest blows struck in the process of making a link. In some private plants the chainmakers use a heavier sledge for this purpose. This was tried in the Boston Navy Yard, but the men preferred to use the same sledge as in welding, and this is the practice to-day.

The most satisfactory way to set the stud is under a hydraulic press with dies so formed as to properly shape the link, removing any deformations that may exist. This will require special equipment in connection with each chain fire or pair of fires. It is desirable, if practicable, to set the stud under the same hammer as is used for welding. This was accomplished in connection with the dies shown in Figs. 29 and 30, by means of the groove "C," shown on the side of the die, which proved exceedingly simple and an easy method for setting the stud. The fact that dies under a large hammer can be adapted to this purpose is an additional reason for the use of such a hammer.

Handling the Chain.—The present method of handling chain is exceedingly unsatisfactory, the chain hanging from a ring or bail overhead as shown in the illustration accompanying description of hand-making process. The importance of suitable handling facilities is frequently overlooked in considering improvements in the chain-making process.

Experiments have been made at the Boston Navy Yard to develop a crane of suitable design, and two types are being tried out. These are indicated in Figs. 31 and 32, Plates 104 and 105, respectively. Both types have certain advantages and are considerably in advance of the crude methods in use at present in connection with the hand-making process.

Heat Treatment.—It is the practice commercially to anneal chain after it has been in service from six months to a year, but no heat treatment is given immediately after manufacturing. Such heat treatment would appear to be necessary, in that it will refine the grain of the iron, remove stresses due to non-uniform heating and forging, render the product more uniform and improve its physical prop-

erties according to the character of the heat treatment given. Such heat treatment may be considered under three heads:

(1) Single heat treatment—slow cooling—annealing.

(2) Single heat treatment—rapid cooling—hardening.

(3) Double heat treatment—rapid cooling and drawing—hardening and toughening.

Tests.—In order to determine the value of these various heat treatments and further the necessity of heat treating chain immediately upon completion and before issue, a set of preliminary experiments was conducted at the Boston Navy Yard, which experiments it is hoped to continue and to extend.

The results of these experiments are shown in Fig. 33, Plate 106. These tests were carried on with very crude equipment and cannot be considered as absolutely correct. They give, however, a very clear indication of the effect produced by heat treatment and the effect of different rates of cooling, and point the wisdom of further experiments along this line. Series "B" covers the same tests as series "A," except that the bolts were tumbled in a rattler in the foundry for about four hours in order to show the effect of vibration. There is a slight increase in tensile strength and elastic limit resulting, but not sufficiently marked to draw any conclusions. However, a slight increase is to be expected, due to the hardening effect of cold working. The tensile strength obtained by cooling in water in series "B" is considered abnormal and not to be relied upon; it should be noted, however, that in series "A" the tensile strength has been raised from 47,500 pounds per square inch with slow cooling in furnace, to 59,000 pounds per square inch with rapid cooling in water. The elastic limit rises with the tensile strength and the contraction of area and elongation decreases with the rise in tensile strength. This wide range of quality indicates the desirability and necessity of suitable heat treatment.

It is probable that between these wide limits there is a mean condition that will give a reasonable tensile strength with satisfactory ductility. It is possible that the treatment, which is most satisfactory from a material point of view, would be too expensive to permit of its adoption. The effect of double heat treatment should be noted in the curves. The material was first heated to 1,675° F., quenched in water and then reheated to temperatures varying from 350° to 750° F. by 100° steps. As was to be expected, this resulted in a decrease in tensile strength and elastic limit and a rise in contraction of area and elongation as the temperature in the second heat was increased. By such a process it should be possible to produce a very satisfactory material, but the expense of such treatment of large chain would be prohibitive. It is worthy of note that such wide variation in tensile strength and ductility can be obtained with a material of such low carbon content—.03 to .10 carbon.

A large furnace for the heat treatment of chain is now being installed at the Boston Navy Yard, and it is expected in the future to heat treat all chain before issuing to the service. This furnace is an overhead checkered crown oil-burning

type with the bottom of the furnace carried on a car so as to permit of charging by use of the traveling crane.

A comparison of the British and United States practice is shown in tabular form in Fig. 34, Plate 107, and in graphical form in Fig. 35, Plate 108. With the repeatedly increasing sizes of chain it is probable that the breaking stress required for sizes about 3¼ inches will have to be somewhat reduced below those indicated on the curve of the United States Navy in that this curve will fall off somewhat after the manner of the Admiralty curve at 2½ inches. There appears to be no good reason for lowering our requirements for sizes made up to the present time.

The usual type of breaks met with in the testing of chain are shown in Fig. 36, Plate 109. The following tables are the result of examination of records of routine tests of chain as manufactured at the Boston Navy Yard. It shows the frequency with which breaks of different types occur:

Chain size.	No. tests.	W_W.		W_A.		W_C.		Q_W.		Q_O.		C_W.		C_O.		C_A.	
		No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.
3	88	22	25	11	12	2	2	18	20	19	21	12	14	3	3	1	1
2¾	42	19	45	0	0	1	2	1	2	17	40	1	2	3	7	0	0
2⅝	14	1	7	2	14	0	0	0	0	8	57	2	14	0	0	1	7
2	20	6	30	0	0	0	0	0	0	9	45	0	0	5	25	0	0
1	7	1	14	0	0	0	0	3	21	3	21	0	0	0	0	0	0
¾	16	3	18	0	0	0	0	10	62	3	18	0	0	0	0	0	0

Chain size.	No. tests.	W_W.		W_A.		W_C.		Q_W.		Q_O.		C_W.		C_O.		C_A.	
		No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.	No. of breaks.	% of total No.
1	30	9	30	1	3	5	17	7	23	6	20	1	3	1	3	0	0
⅞	117	25	21	12	10	0	0	62	53	14	12	4	3	0	0	0	0
¾	35	1	3	6	17	0	0	17	48	7	20	1	3	3	8	0	0
⅝	14	0	0	5	36	0	0	6	42	2	14	1	7	0	0	0	0
½	14	1	7	2	14	0	0	5	36	5	36	1	7	0	0	0	0

DISCUSSION.

NAVAL CONSTRUCTOR OTTERSON:—Mr. Howard is present. He was the inspector of the chain made at the Navy Yard for the Panama Canal Commission. I hope that he will take part in this discussion, and probably state the results obtained from his inspection; and, if he is in a position to do so, to include in his discussion some of the notes from his report on these tests, which I think were rather interesting.

THE CHAIRMAN:—Mr. Howard, do you feel like saying something on this question?

MR. JAMES E. HOWARD, *Visitor*:—Mr. Otterson has gone over the subject of the manufacturing details in the making of chain exceedingly well. My remarks, therefore, had better be along other lines, since he has covered the manufacturing details much better than I could.

In regard to material, it seems that the best results have commonly been obtained with puddled iron, of not too high a degree of refinement. When iron is refined to the extent of almost reaching a puddled steel there is danger of brittleness in the manufactured chain, and in the subsequent use of the chain such brittleness will manifest itself.

The fabrication of bar iron into the form of a link necessarily puts it into such shape that there is not a good distribution of stresses in the cross-section of the sides of the links, and probably very little chain is used which under service conditions is not overstrained, at least in some of its parts. Such overstraining may and in many cases does lead to ultimate brittleness. As an illustration of such a tendency in plain bars, there were some single refined and extra refined puddled irons tested in the early days of the Watertown machine, which originally had a tough and fibrous character. After an interval of rest, following the original test, the material gradually became brittle in the fracture upon subsequent tests being made. In the course of a few years, the fractures, which were made in retesting from time to time, changed from fibrous to granular. This was accompanied, however, by increased tensile strength, the iron originally having shown a tensile strength of about 51,000 to 52,000 pounds per square inch, but which finally rose to some 64,000 pounds per square inch. Annealing restored the iron to its fibrous and tough character, at the same time bringing the tensile strength down to about its original value.

There is a feature of interest in regard to chain cable which should be considered and which pertains to the location of the place of fracture, when a link breaks in service. Many links, after the chain has been in service, break not at the weld, but in other places in the quarter at the opposite end from the weld or elsewhere, and such service fractures are commonly brittle ones. This is thought to result from frequent bending, slight in extent it may be, but occurring in different parts of the link.

Having a soft and tough fibrous iron at the outset, obtained by proper selection of material, it is desirable to keep it so. Applying a proving stress to a chain, say one and a half times its working load, overstrains it in a degree, and to some extent this is detrimental. After a manner the proof stress has an effect similar to the testing of the puddled iron referred to—it may introduce a tendency in the iron to become brittle. It would be safe practice to anneal chains after proof stresses have been applied, and in order to maintain a state of toughness the annealing should be repeated after there have been overstraining loads on the chain.

In reference to the fender chain for the canal locks at the Isthmus, it was recommended that it be annealed if perchance it was called upon to stop a ship and thereby subjected to severe straining—to anneal after each such occasion.

In order to assure ourselves that good welds have been made in the chain, proving stresses are necessary, and to be efficient they should be somewhat above the working stresses. Furthermore, the proof stresses should be sustained by the chain a reasonable length of time, long enough to exhaust about all the stretch of the links which the proof stress is capable of causing. In the subsequent use of the cable the links will not assume the same positions as in the proof tests, but will act upon each other differently, in consequence of which there may be an increased stretch, even if the approach to the proving stress were not very close. But the only assurance we have of good welded links is found in the results of the proof test.

In the making of welds, if we could get the material into close contact at a suitable temperature and some mechanical work given the iron at that time, an excellent weld would result, and possibly the junction of the welded parts might not be detected even microscopically. Such a weld was in fact made in some experimental work with a mild grade of steel. The welded surfaces were brought together with a rubbing movement, one side against the other, and so well were the surfaces united that well-defined crystals spanned the junction, as found upon subsequent examination of a polished and etched surface.

A bodily sliding or rubbing movement seems to facilitate welding, as many short and slightly oblique butt welds have shown. With long scarfed ends, overlapped and hammered down, there is danger of enclosing cinder or in closing down upon each other oxidized surfaces which will not weld.

Chief Constructor Richard M. Watt, *Vice-President:*—I simply want to add to this paper the fact that it represents several years' exhaustive study on this subject, and that in his capacity as shop superintendent of the Hull Division of the Navy Yard at Boston, Mr. Otterson has markedly improved the output of chain at that yard, so that his efforts have resulted in the saving of many thousands of dollars to the government. I believe that that attention, which has so increased the hand output, will in time develop an entirely satisfactory method or process of power manufacture of chain.

Mr. Francis T. Bowles, *Past President:*—No doubt we are under many obligations to the author of this paper for the information he has given us, and I do not want to appear as too discriminating when I suggest that notes on the subject of chain cable are absolutely incomplete without any reference to the subject of swivels and shackles. My own interest in the subject of chain cable is entirely connected with operating troubles with shackles and swivels which cannot be properly described in polite language.

Mr. Robert Haig, *Member* (Communicated) :—With regard to the statement made on page 158 of Mr. Otterson's paper it is hardly correct to state that "Lloyd's will not accept chain made by this process;" the real facts are that as test links must be cut out of every 15 fathoms the makers have not yet been able to put in a joining link with the machine as it is found difficult to bunch the two ends of the chain on to the one link, but while this no doubt will yet be accomplished, at present joining links have to be put in by hand, and as this brings the strength of the chain down to that of iron hand-made chain the value of the mechanical process is somewhat neutralized.

The question of heat treatment or annealing of cable chains for merchant vessels is not practicable and is very wisely not indulged in, as with cast-iron studs as are usually fitted in cables for merchant ships, heating of the chain causes a swelling of the studs and in many cases produces cracks and also has the bad effects of loosening the studs in the links.

There does not appear to be anything novel or unpractical in welding heavy chain under a steam hammer, although we have had side-welded chain of 3⅜-inch iron made by hand in Pennsylvania, which when tested was found to be of the very highest quality of chain and presented no difficulty in making.

Mr. Otterson's paper is most interesting.

THE CHAIRMAN:—If there is no other gentleman who desires to discuss the paper, we will be glad to have Mr. Otterson make such reply as he cares to.

MR. OTTERSON:—I think that the future development of the manufacture of chain, as regards the material, will probably be along the lines suggested by Mr. Howard, and that we will go into larger sizes to the use of a softer and more ductile material. We have recently received a shipment of material of this character, and while in the straight specimen it gave rather low test, yet when formed into links the tests were very satisfactory, the probability being that the ductile material under deflection flowed more readily and subjected itself to less strains than the harder and more brittle material.

I want to express my appreciation of Admiral Watt's remarks. I might say, with the process developed to its present form, and the links turned over to the chainmakers, that it will be possible for them to increase the output one hundred per cent, or more. I do not say they will increase it; we will probably have difficulty in making them do it, but it is possible for them to increase it.

In regard to the remarks of Admiral Bowles, as to the question of shackles and swivels, I might say that discussion of those features has not been included in the paper for the reason that we have not had as much trouble with the manufacture of shackles and swivels as we have had in the manufacture of chains, and they are at present manufactured by machine process. I feel that any troubles which have been experienced have been more in the testing and service of these appliances, and with their fit on the wildcat.

THE CHAIRMAN:—I am sure you all desire to express your appreciation of Mr. Otterson's paper, and on your behalf I will extend to him the thanks of the Society.

The next paper is No. 16, entitled "Model Experiments and Speed Trials of the 60-Foot Motor Cruiser Kathmar II," by Mr. A. E. Luders.

Mr. Luders presented the paper,

MODEL EXPERIMENTS AND SPEED TRIALS OF 60-FOOT MOTOR CRUISER KATHMAR II.

By A. E. Luders, Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

Having been able to make a great deal of use of the various papers on the subject of resistance of ships and models read before this Society, it has occurred to the writer that possibly similar data of a type of vessel that has not been touched upon in previous papers may prove of interest.

For this purpose Robert T. Fowler, Esq., the owner of the 60-foot gasoline cruiser, Kathmar II, kindly placed this boat at my disposal and a number of runs, results of which are plotted on a curve sheet, were made. To supplement this practical information the Navy Department most courteously agreed to make and test a model of this boat under similar conditions of draught, their interest making this paper possible.

The results of the model experiments as made by them are given on the same plate as the other information.

The trials were over the New York Yacht Club Course, 1.1 knots at Hempstead Bay, where four double runs were made.

Kathmar II was launched in the spring of 1911, at which time she floated—in light cruising trim—at her designed load water line. The difference of displacement on the 1913 trials is accounted for by the boat being deeply laden, preparatory to starting on an extended course, by soakage and the gradual augmenting of equipment, etc., that occurs from season to season.

The bottom of this boat had not been painted for three weeks and was undoubtedly soft, though not foul. This probably explains somewhat the increase in horse-power over model experiments by an amount that indicates that the actual skin friction was practically double the theoretical.

The increased horse-power required to drive the boat with the stern cut off square at the waterline was unexpected.

The effective horse-power from trial was deduced from the thrust of the propeller (the wheel being deeply immersed, only 3 per cent of wake was assumed), and using results of Professor Durand's investigation (Vol. 4) as a basis from which to work by the laws of comparison of similar propellers. On the basis of a propulsive coefficient of 65 per cent the horse-power at the 10.26-knot point agrees well with the brake test of the motor.

In general, the design of Kathmar II proved very satisfactory in seaworthiness and stability, and was somewhat faster than similar boats of the same power.

DISCUSSION.

The Chairman:—This paper, No. 16, "Model Experiments and Speed Trials of the 60-Foot Motor Cruiser Kathmar II," is now open for discussion. No doubt there are a number of our members who are interested in this question of trials, model experiments, and that class of experiences, and as the paper undoubtedly contains valuable information, I think that some one might, perhaps, care to say a word in discussion of the paper. If there is no discussion, we will extend the thanks of the Society to Mr. Luders for his paper.

The next paper is No. 17, entitled, "Some Graphic Studies of the Active Gyro Stabilizer," by Mr. Elmer A. Sperry.

Mr. Sperry, in presenting the paper, said:—

"I desire to make just a brief reference to the work that has recently been done the world over on the study of rolling. The work of Frahm, supplementing as he did the original work of Sir Philip Watts, opened up anew these experiments. Coming from Italy, from the hand of the great Commodore Russo, there was a very valuable contribution to our knowledge of the rolling of ships, especially in the effort to dampen such rolling by the use of tanks. This work was about simultaneous with a very able paper by Sir Philip Watts, read before the British Institution a year ago, and which in turn led Sir Philip and Professor Biles, another original worker in this line, to encourage further experimentation in England, and as a result two important papers were read before the institution this year. That by Professor Woollard was especially gratifying in checking up the results obtained by Commodore Russo, and also in developing the fact that tanks at certain points in the phase relation between ships and waves are positively dangerous.

"Professor Woollard's paper, Fig. 2, referred to in the last part of my paper, which illustrates the damping power of tanks for different phase relations between the ship and the sea, very graphically illustrates the well-established fact that tanks have their greatest stabilizing power when the sea is synchronous with the period of the ship, and that there is a region each side of this region of synchronism, and quite close to it, where the power of the tanks falls to very low values, then rises a little both to the left and to the right, but attaining in neither of these regions more than a small fraction of its power at the point of synchronism. In the present experiments I have been careful to explore this same region, starting away below synchronism and passing through synchronism to points considerably beyond, with the results given in Plates 113 and 114.

"In this connection it is interesting to note that whereas the usefulness of the damping tanks seemed to depend almost entirely upon the phase relation between the period of the ship and the period of the sea, with the gyroscopic stabilizer its usefulness seemed to be entirely independent of any phase relation and its demonstrated efficiency in sea trials seemed to be well above 90 per cent, and in instances above 95 per cent, for all phase relations and under practically all conditions.

"With reference to the two large plates showing the curves, I wish to call your attention to the quite marked difference in frictional resistance between the cycloid model used in the present work and that of the model used in the most widely published experimental data we have in reference to tanks. In Fig. 24, Plate 113, some of the curves in reference to tanks have been reproduced. The extinction curve of the tank model is shown at the extreme right, Fig. 24, whereas a small extinction curve of the gyroscopic model is shown at the extreme left in Fig. 1, Plate 113. By examining this curve we see that there is a reduction

of about 3½ degrees per roll at the beginning, in the middle about 2 degrees and about 1¼ degrees along about the tenth roll. The friction coefficient shown by this curve is about .35, or about five times that of an ordinary battleship, whereas the coefficient shown in the model presented herewith is about 1/35, or .01. I call attention to these facts because they have a significant bearing on the extinction and rolling. In the tank model the natural friction of the model contributed very largely to the results, whereas in the gyroscopic model the contribution is almost insignificant.

"Referring to the four extinction curves shown under Fig. 24, we note that to the large quenching increment in each case there should be added the quenching increment due to the natural extinction. When these additions are made, reading from left to right, the full alleged quenching increment becomes, respectively, 6.44, 3.99, 6.725 and 4.74, which it will be noted in each case brings the total quenching increment above, and in most cases considerably above, the wave increment. For instance, in the first to the left the quenching power is somewhat over twice the wave power, in the second it is 25 per cent in excess, in the third 43 per cent in excess, and in the fourth only slightly in excess. But in none of these curves is the quenching good. In the second and third curves we would hardly call a ship swinging through 10 to 12 degrees as being held against rolling, and in the last curve practically no quenching whatever is shown as the ship here is swinging through an arc of 44 degrees. Yet, I repeat, in each of these instances the quenching power is in excess of the power of the wave received by the ship.

"In this connection I wish to especially call attention to the fact that where the quenching power is greatly in excess of the wave power, or where it is only to a small degree in excess, or where the quenching power equals the wave power, roll quenching by the gyro is practically complete in every instance; in fact, the gyro stabilizer quenches all rolling increments below and up to an equality with its powers so completely that the boat never gets away and never starts rolling, and therefore no curves of this kind, where the stabilizing power is in excess of the wave power, are shown in connection with this paper because operation under these conditions is too easy.

"The interesting point is: what happens when the wave power is equal and in excess of the roll quenching power of the gyros, and curves of this character only are shown in connection with this paper. All ratios below, as stated, are too easy and present no problem that is of practical interest. It will thus be seen that this work is quite in contrast to the widely published results with models supplied with damping tanks where the roll quenching power was always in excess of the wave increments reaching the ship.

"In curves 3 and 12 the gyro was used to roll the model.

"On the lower line of each plate are given curves for different phase relations between the ship and the sea, starting at the right with waves shorter and passing through synchronism to waves that are longer than the natural period of the ship. Attention is called to the fact that the wave increment in each case is in excess of the quenching increment, this ratio being varied until the gyro fails in a measure to hold the ship, giving very graphically what may be expected of the gyros under conditions where the ship is receiving wave increments that are apparently considerably in excess of the powers of the gyro, in fact, greater wave increments than the gyro stabilizer should be expected to handle and suppress. Connected with each of these curves is a portion where the gyros are cut out so that the effect upon the ship of the sea running at the time is made instantly apparent.

"The plant shown in Plate 115 was constructed for the Bureau of Construction and Re-

pair of the United States Navy, for the use of Naval Constructor D. W. Taylor in investigations of the torque actually received from waves by a large series of models with different form lines. Under the peculiar conditions of the operation of the gyro stabilizer, which, it may be stated here, are probably unique, the model may be held free from motion while it is receiving heavy torques, and the amount and direction of these torques may be measured by the amount and direction of the precession angles of the gyro.

"The recording mechanism is also mounted upon the model together with a model gyro roll recorder, which was shown in my paper read before this body last year, the actual roll record and movements of the stabilizing gyro frames being recorded side-and-side on the same tape. In this manner the impingement of the waves upon the model, which would cause it to roll excessively and through wide angles, really causes vigorous and wide angular movements of the precession frames of the gyro stabilizer only; but the ship's model does not move, giving at once a beautiful opportunity to measure the torque actually received by the model from waves of various heights, periods and angles to the model, and at the same time beautifully demonstrating the capacity of a gyro stabilizer to very completely prevent rolling, which without the stabilizer would be excessive and which in a full-sized ship would render the ship uninhabitable.

"In Plate 115 the control, which has finally been standardized, is shown to the right and operates entirely by angular velocity of roll of the model. By this device all difficulties with wind list, or permanent list, are done away with; that is, the particular position as to the vertical about which the ship tends to roll is a matter of entire indifference to this form of control; it is found to operate at equal efficiencies with the ship in any position of permanent wind list.

"I might call your attention to one interesting feature of Plate 117, which you have before you, and that is the wave-maker. Heretofore on roll-pendulums, and in similar experiments, various methods for using springs in imparting wave momentum have been used which were open to objections, but here is a wave-maker which is practically free from such objections. You will notice in the foreground a cast-iron roller which rolls back and forth on a platform, giving an impressed moment on the pendulum which is perfectly sinuous and which gets very close to the absolute theoretical requirement; this is especially true, as you will see on Plate 118, as the pitman operating this wave-maker has some twenty times the radius of the crank, so that the effect of the angular component of the wave-maker is almost wholly eliminated. The recording apparatus is also shown on this last plate, by which we were able to record simultaneously the waves and the oscillations of the ship.

"Plate 118 shows the method of recording and includes simultaneous diagrams of the wave-maker and the resulting oscillations of the pendulum. The simultaneous diagrams form a large part of the work but are not referred to in the present figures.

"Plate 116 shows the general disposition of the weights with which the cycloid pendulum was loaded.

"I thank you for your kind attention."

SOME GRAPHIC STUDIES OF THE ACTIVE GYRO STABILIZER.

By Elmer A. Sperry, Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

The present wide interest in stabilizing ships and the large amount of study recently given this subject has led us to some extended studies to secure further experimental data and records of actual performance under varying conditions. In this connection some of the tests have been made parallel to some of the later work done by others, so that comparisons can readily be made.

The experimental apparatus consisted of a cycloid-pendulum in the form of a rigid platform on which an active gyro stabilizer and its control were mounted provided with an upper extension and lower shelf for accommodating the weights required to establish any desired characteristics in pendulic height, period, and total weight. This structure rested on two ⅞-inch diameter steel rods on steel plates and could roll thereon. It carried on one end a horizontal running board or track on which a weight, chiefly in the form of a heavy iron roller, could perform reciprocating motions symmetrically with respect to the axis of the pendulum; this was positively reciprocated by a motor-driven crank acting through a very long, light connecting rod.

The weight itself, the period of its motion, and the crank radius were adjustable, thus providing for the exertion of sinuous moments closely corresponding to those exerted by a series of regular waves of definite slope and period on a floating body. The motion of the moving weight deviated only very slightly from the ideal owing to the connecting rod being about twenty times the crank radius and although the motion of the pendulum was somewhat different from that of a vessel amongst waves, in certain vertical components these may be neglected and the results as expressed by the records are essentially correct for the reason that the gyros are not affected by any but angular motion.

The recorder consisted of a constant-speed, motor-driven drum. The recording pencil derived its motion directly from the pendulum itself by means of a long connecting rod.

The active stabilizer consisted of two small gyros coupled for opposite precession on their vertical axis by means of a locking worm drive, the worm shaft was driven by magnetic clutches, operated by an automatic control, from either of two discs rotated in opposite directions at a predetermined and comparatively low speed by a small shunt-wound motor. In their center position the spinning

axis of both gyro rotors was horizontal and at right angles to the rolling axis of the pendulum. The possible precession angles were limited to 60 degrees from their center position by automatic switches opening the clutch circuit just before the angles mentioned were obtained and mechanical stops, set for these limits, provided a positive limit.

The motor speed, and thereby the precessional velocity of the gyros, could be varied. The value of one of the fundamental features of the active gyro, that of establishing an absolute upper limit of the precessional velocity and therefore of the stresses in the plant and also in the ship in the vicinity of the plant, was recognized throughout the tests. The rotors of the stabilizer, as well as that of the control gyro, were run at any desired speed by three-phase current obtained from a motor generator, the speed of which was under control. The automatic control was of the type responsive to angular velocities and was represented by a third gyro with its spinning axis also horizontal, athwartships, and able to precess about one degree only to each side of the center position, in which it was held by adjustable centralizing springs. An angular roll would first overcome the pressure of one of these springs and then compel the slight precessional motion, which closed one of the circuits of the magnetic clutch, causing precession of the main gyros in such a direction that the stabilizing moments result in quenched roll in the direction which closed the contact. The contacts can be positively closed by the angular velocity of a ⅛-degree roll of 2.9 seconds period, thus insuring precession almost coincidentally with the beginning of even an incipient roll for close stabilization. The stabilizing gyros, which are strictly non-pendulous and always locked, are by this principle of control never allowed to precess in the wrong direction, increasing the existing roll, nor allowed to precess too far, which would cause a reversal of roll in its phase. Another important point is that such a stabilizer remains unaffected by the positive couples set up by the gyros themselves, due to angular velocity of any unquenched roll.

This simple control is found to work well for wave impulses within the capacity of the stabilizer, and close stabilization is certain and reliable. Should an impulse occur that is larger than the capacity of the gyros, a slight unquenched residual roll results, the centralizing springs being overcome at a definite velocity of roll. The larger the roll entered upon, the sooner this velocity is attained after the start of any individual roll. For maximum efficiency of the stabilizing moment of the gyros their precession should be so timed that they pass through their central position at the moment the vessel has attained its maximum velocity in the middle of its roll, and it is found that the efficiency of the plant may be increased slightly by retarding the action of the controller at times when the momentary angular roll of the vessel exceeds a predetermined amount. It is found that this may be accomplished automatically by the single augmentation of the centralizing spring pressures as by the addition of a simple pendulum.

The problem of main journals on the stabilizing gyros has been found to solve itself. The frequent and complete reversal of the journal pressures with every half

period insures perfect lubrication throughout the pressure-free bearing surfaces so that ordinary bearings with liberal allowance for oil space are found to run cool under extremely high, periodic, specific pressure, while both the very high velocity and pressure insure the very low frictional coefficient which is realized in practice.

Theoretically a synchronous wave of the apparent slope α will produce, when passing a floating body, a maximum amplitude of $\pi\alpha^\circ$, or result in two single roll increments of $\frac{\pi}{2}\alpha^\circ$ each, when considered as frictionless. Correspondingly, if the maximum plus and minus moments of our mechanical wave producer, when at rest, inclined the pendulum α° from the vertical, corresponding increments, $\frac{\pi}{2}\alpha^\circ$, should be obtained for synchronous conditions. This was indeed very nearly the case; the minute deviations found are due to the slight friction, and also the difficulty of starting the wave-maker instantly at full speed.

The angular momentum that a sinuous couple, the maximum value of which would incline a vessel α°, will impart to such a vessel, during one-half of an harmonic oscillation, is equal to $\frac{2}{\pi} \times$ its maximum value $\times \frac{T}{2}$, or $\frac{T\,2240\,Dh \sin\alpha}{\pi}$ in pounds, feet, seconds, when,

T = full period of vessel and of the couple in seconds.
D = displacement of vessel or weight of pendulum in tons.
h = metacentric height or pendulic height in feet.

This momentum must be balanced, for close stabilization, by that produced by the stabilizer, which according to the well-known formula is equal to

$$k^2 \frac{W}{g} \frac{R\pi}{30} \Sigma \sin\phi,$$

in which

k^2 = radius of gyration of the rotating mass in feet^2.
W = weight of rotating mass in pounds.
R = number of revolutions per minute of this rotating mass.
ϕ = angle of precession from the center position of the gyro to each side,

therefore,

$$2240 \frac{T}{\pi} Dh \sin\alpha = k^2 \frac{W}{g} \frac{R\pi}{30} \Sigma \sin\phi.$$

For small angles $v\alpha$, we can substitute

$$\frac{\pi}{180}\alpha = \sin\alpha,$$

consequently,

$$\alpha = \frac{k^2 WR \Sigma \sin\phi}{DTh\,3822}.$$

This gives the maximum wave slope in degrees, or the inclining angle due to the maximum of a sinuous couple, against which a stabilizer with the characteristics k^2WR would hold very closely a vessel pendulum with the characteristics DTh.

When unrestricted the roll increments equal

$$q = \frac{\pi}{2}\alpha.$$

For each half period the individual roll increments quenched would be

$$q = \frac{\pi}{2}\frac{k^2\ WR\,\Sigma \sin\phi}{DTh\ 3822}.$$

Should the precession angles be 90 degrees the precession velocity could be constant and equal to the phase velocity of the wave, or $\frac{2\pi}{T}$. Since the maximum of the stabilizing couple must also be equal to that of the wave, we have

$$2240\,Dh \sin\alpha = k^2\frac{W}{g}\frac{R\pi}{30}\frac{2\pi}{T},$$

and again

$$\alpha = \frac{k^2\ WR}{DTh\ 1911},$$

which gives the same result as the general formula for $\Sigma \sin\alpha = 2$.

The work done by the gyros depends on the angular velocity of the body on which they act and would become a maximum when the entire momentum was exerted at the center of the roll. This would give an effect of the stabilizer of

$$q = \frac{4}{\pi}\frac{\pi}{2}\frac{k^2\ WR\,\Sigma \sin\phi}{DTh\ 3822}$$

as unity. This, however, is largely of theoretical interest, but useful as establishing a base line.

The properties of the pendulum from which the curves were taken were:

Total pendulic weight, 615 pounds, or .2746 ton.

Pendulic height, found from inclining experiments, .36 feet.

The period was 2.9 seconds giving the characteristic $DTh = .287$.

Suppose this model represented a ship reduced at the ratio of $\lambda = 30$, it would then represent a ship with the characteristic

$$DTh = \lambda^3 \times \lambda \times \sqrt{\lambda} \times .287 = 1{,}273{,}000$$

for instance $\begin{cases} D = 19{,}000 \text{ tons.} \\ T = 14 \text{ seconds.} \\ h = 4.78 \text{ feet.} \end{cases}$

Each of the gyro rotors had the following properties: $k^2W = .2188$ lbs.-feet^2, and therefore an impulsive or maximum roll quenching power of

$$q_{\max} = \frac{.2188 \times 1.732}{1911 \times .287}R = \frac{R}{1450}.$$

The scale for the records given was obtained by forcibly tilting the pendulum definite angles and holding the same momentarily with the recorder operating.

It will be noted in the formula previously given that the impulsive performance on the part of the gyro is assumed as datum or 100 per cent. This being an engineering impossibility from a practical standpoint, it has been suggested to adopt a more practical unit, consisting of the efficiency obtained by the constant precessional velocity of two times the phase velocity of the ship, for the reason that this phase velocity is so slow, especially for large ships, that it may be attained almost instantaneously. This, therefore, will be used herein as the basis on which the efficiency obtained in these experiments will be calculated.

Amongst others, the following characteristic curves were produced:

1. Extinction Curves, made by tilting the pendulum to 20 degrees and releasing it with one or two gyros in action (see Figs. 2 and 11, Plates 113 and 114). The quenched increments were for $\alpha = 2^\circ$, $q = 2.69^\circ$; for $\alpha = 3^\circ$, $q = 4.36^\circ$, when deducting the small corresponding friction increments, taken from the natural extinction curve, this indicates an actual efficiency of .94 for $\alpha = 2^\circ$, and .96 for $\alpha = 3^\circ$; when based on the efficiency described above.

2. Rolling Curves (Figs. 3 and 12, Plates 113 and 114). These were made by reversing the control contacts, tilting the pendulum about one degree to insure an initial movement, and then releasing it. The roll increments produced when adding the corresponding friction increments were 2.75°, 4.7°, and 2.25°. The efficiency indicated was .965, .99 and .95, on the same basis.

3. Curves showing the performance of the stabilizer when the pendulum was subjected to a succession of uniform waves. For these experiments the weight producing the wave moment was adjusted until the maximum moment produced an inclination of α° corresponding to the maximum moment of a synchronous wave of α° slope. Figs. 4-23, Plates 113 and 114, show the effect of one gyro and of two gyros against 2 degrees and 3 degrees wave slope, respectively. In curves, Figs. 6, 7, 18 and 19, the stabilizer was stopped, and, after several synchronous increments, thrown in again to show that the stabilizer actually worked close to its capacity as the resulting extinction curve nearly coincides with the natural friction extinction curve, which emphasizes the close correspondence between the figured and actual roll quenching power, and also the striking fact that close stabilization can be relied upon even when the figured roll quenching power is actually less than the wave increments.

Since the mass moment and frictional moment of the stabilizer are entirely eliminated by active control, the closeness of the stabilization obtained will depend only on the sensitiveness of the control, which, for the definite speed of the control gyro, is proportionate to $\frac{1}{T}$, where T is not the period of the vessel or pendulum, but of the wave. This is due to the fact that a stabilized vessel or pendulum will no longer roll in its own phase, but will, almost immediately after the stabilizer is thrown in, fall into forced roll and adopt the wave period. Closer stabilization

is obtained when the wave period is shorter than the natural period of the vessel or the pendulum. This is clearly expressed in Figs. 4, 5, 9, 15 and 23, Plates 113 and 114. These demonstrate the quenching effect of the stabilizer for wave impulses of shorter and also longer phase than that of the pendulum. The close quenching capacity for wave impulses having any period can be had from the main quenching formula by substituting for T the period of the wave.

The wave impulses chosen for Figs. 9, 13, 16, 22 were really beyond the capacity of the stabilizer, resulting, as anticipated, in unquenched roll. This performance stands out in strong contrast with the performance of anti-rolling tanks under similar conditions, which invariably show on both sides of synchronism a marked falling-off of the stabilizing power as expressed by very large unquenched forced roll at these points. As bearing on these points one cannot do better than to refer to Fig. 2 of the extremely able work of Lloyd Woollard in his paper presented before the Institute of Naval Architects in June, 1913.

In estimating the quenching power of tanks for purposes of comparison, the friction increments caused by any unquenched roll should receive due consideration, as these increments act as a powerful aid which has been wholly neglected by some investigators.

From model experiments with anti-rolling tanks, which were widely published, the curves, Fig. 24, were obtained under the following conditions, figured roll quenching increments of tanks for synchronous waves: Tank No. 1, $q = 2.99$ degrees; tank No. 2, $q = 2.835$ degrees; figured from data furnished. The model showed an extinction curve given by Fig. 24. The following deductions can be made:

Roll increment.	Unquenched roll.	Friction increment.	Alleged quenching increment.	Actual increment quenched.	Alleged quenching increment; actual increment quenched.
3.14°	2.5°	.51°	5.825°	2.63°	2.21 fair quenching
3.14°	7.6°	.8°	2.99°	2.34°	1.275 poor quenching
4.71°	6.0°	.64°	5.825°	4.07°	1.43 poor quenching
4.71°	22.0°	1.73°	2.99°	2.98°	1.0 poor quenching

These data refer only to synchronous conditions. In cases where the waves are not synchronous the positively controlled gyro stabilizer is in a class by itself. Its lack of any period and mass moment allows it to closely stabilize, at a maximum efficiency, wave moments resulting from any sea, and when the demand upon it is far beyond its capacity it invariably deducts its full decrement from each single roll impulse, and practically without power on the part of the precession motor, and, moreover, is found to positively operate at increased efficiency under these conditions.

It will also be found that the weight required for an active gyro stabilizing

plant will be less than one-third, and the space required less than one-tenth of that required by anti-rolling tanks as practically located and applied to vessels for equal roll quenching power.

Plate 115 shows the active gyro stabilizer to the left and the controller to the right with the precession motor between. This plant is designed to deliver to a model of the 32,000-ton battleship, having a ratio of 30 to 1 and a period of 2.97 seconds, a control impulse of from 4 degrees to 5 degrees per half period or up to 10 degrees per period. Such a model really amounts to a boat of quite large proportions, whereas the comparatively small size of the stabilizing plant itself, even when running at extremely low stresses, is brought out by the fact that the wheels are only 5 inches (13 cm.) in diameter by 2 inches (5 cm.) face. They run at only about 2,000 pounds per square inch (146 kg. per square centimeter) maximum fiber stress for the wheel.

Plate 116 shows the back view of the cycloid-pendulum and the stabilizing plant. The pendulum load approaches one-third of a ton, having the various characteristics described in the paper. This view also shows some of the elevated weights.

Plate 117 shows the forward view of the cycloid-pendulum and also the wave maker consisting of the platform upon which reciprocates the solid iron roller. The end of the long pitman is also shown in this plate. These impressed forces act almost perfectly as a pure sine wave function.

Plate 118 shows the operating end of the long pitman of the wave maker and also the double recording device, by means of which most of the records were taken, giving the exact relative timing of both the impressed forces and the resulting behavior of the "ship" under conditions of various friction factors, various stabilizing moments and a wide range of phase relations.

DISCUSSION.

The Chairman:—Mr. Sperry's paper is now before you for discussion, gentlemen. I do not know whether it is with you, as it is with me, but I think there are probably few people who understand all the mysteries of this system, so most of us do not feel competent to discuss it; but, undoubtedly, there are some gentlemen who have gone into it carefully and do understand it, and they may be able to discuss it, to some extent.

Mr. Sperry:—Possibly there may be some questions; I will be glad to tell you anything we have learned.

The Chairman:—Of course the object of discussion is to throw light on the question, and if there is any gentleman who would like to ask questions that will shed light on the matter, we would be glad to hear them.

Mr. H. C. Higgins, *Member:*—I would ask how much space the stabilizer occupies.

Mr. E. L. M. Sivard, *Member:*—I would like to know about what Mr. Sperry mentioned earlier in the day, about some observations he had made on the influence of the gyroscope stabilizer on the stresses of the ship—if there are any data on that subject, I would like to have them.

The Chairman:—Apparently there is no further discussion, Mr. Sperry, except these questions which have been asked.

Mr. Sperry:—Mr. Higgins asked a question as to how big the stabilizer is, how much space it occupies, and that is important. It is brought out in this paper and the one last year that it occupies only a small percentage of the space occupied by the tanks and weighs only a fraction of their weight. You can understand that the stabilizer plant for any ship will depend on how large a single wave increment you require the plant to stabilize against. The constructors in our navy have made a study of this factor; conceive of a single wave increment large enough to throw a great warship over 3½ to 4 degrees, a very large contract, because the rolling of a ship is usually a matter of an accumulation of a great many increments; it is very seldom that any one increment rolls a ship greatly; it is usually an accumulation of smaller increments. Referring, however, to the individual increment, suppose we were to stabilize a ship against 4 degrees single increment, or 8 degrees per period, a large quantity as you will observe, more than twice the stabilizing power heretofore proposed for battleships. Such a roll would require a wave of more than 2 degrees apparent wave slope against which the ship must be held, and we must remember that the wave moment would have to maintain itself for, say, 8 seconds, while the great mass of the ship is getting under motion. Very few waves persist for any such period of time. Now, then, figuring 4 degrees stabilizing power, or 8 degrees per period of the ship, the whole stabilizing plant, everything included, would be a little under 1 per cent of the total displacement. As a matter of fact, you could hardly find it in a battleship, it is so small. This is quite well illustrated by the model. This model is much more than full size for the model of a 32,000-ton battleship, large enough to carry about 20 persons, and yet this stabilizer plant could almost be put in an overcoat pocket; besides, I think those who have had experience will agree with me that a model equipment can never be built as small in proportion as the full-sized plant. For instance, these wheels are so small that their stresses are away down, only a few hundred pounds per square inch, even at the high speeds which they attain. Of course we would never think of putting a wheel in a battleship that did not have as much maximum stress, certainly, as occurs in the hull, yet a spinning wheel at moderate stress is one of the safest things in the world, because you cannot imagine anything happening which will do but just one thing, that is, stop it; nothing can happen to accelerate its speed because its air frictional power consumption increases as the cube of its speed. A certain amount of power put into it will bring it up to a certain speed and bump its head against this law. Unless you get a great deal more power into it you cannot drive the wheel very much faster; and where is this power to come from? The motor is small and purposely limited in size. Then, again, we run away below the elastic limit, and when the elastic limit is reached the wheel, which is still perfectly safe, will then flow and swell. There is a rigid casing close to the wheel and long before any danger point was even in sight a slight swelling

of the wheel would grasp this outside casing and make an automatic brake. This fact was used by Howell years ago with fine effect; he allowed the wheel to swell about 1/32-inch before making its own brake. It is a fact that the size and the weight of the plant are extremely small and its safety is practically perfect.

As to the matter of stresses in the hull that was inquired about, my observations as to the stresses present were these. We were experimenting with a comparatively large ship, in heavy storms; toward the latter part of the tests we became very particular and would not go out until it was blowing up strongly and a very heavy sea running, as reported by wireless by the pilot ship standing at sea out of this port. We were also given a consort when we went to sea on these occasions. Many observations were made. We put on jumpers and crawled under the deck and did everything we could to detect the slightest signs of stress or duress in all parts near the plant, but there were no apparent stresses or deformations whatever. We knew exactly what the stabilizing forces were, and when we were holding the ship from beginning to roll she simply rode the sea, and there is no reason why, while riding the sea, the stresses involved should be as large as when rolling. No stresses are caused in the hull by the precession motive forces as the forces themselves are almost zero. In fact, we obtained many checks upon the power of our precession motor, and it was found to be almost nothing when holding the ship. We found mathematically several years ago that the power should be zero when holding the ship against even heavy seas. The tendency to roll is there, but this is taken care of by equal and opposite forces—forces, mind you—the motion is absent. That means zero power. We found that absolutely on our precession motor; it required next to no power; we could turn the steam away down from the boiler pressure of 150 pounds, and when we had 15 pounds of steam on our little precession engine she handled the apparatus perfectly in the heaviest sea. Perhaps this will tell you something of the stresses—you can see that they did not exist from this source; their amount is perfectly well known and clearly defined, and is extremely low and easily cared for.

The Chairman:—I am sure you all desire me to extend the thanks of the Society to Mr. Sperry for the amplification of his paper in the extemporaneous remarks which he has made. I do that with pleasure.

We now come to the last paper on the program, No. 18, entitled "Electric Propulsion on the U. S. S. Jupiter," by Mr. W. L. R. Emmet.

In presenting his paper, Mr. Emmet reviewed the subjects touched upon in it and related experiences in the operation of the Jupiter. He explained the great economy and practical advantage of the modern high-speed turbine as it might be applied to ships, either through the medium of electrical apparatus, or of gearing. He explained the advantages which electric drive afforded as compared with gearing, and expressed regret that the U. S. Government had not done more to realize the very particular advantages which this method offered in a large warship.

ELECTRIC PROPULSION ON THE U. S. S. JUPITER.

By W. L. R. Emmet, Esq., Member.

[Read at the twenty-first general meeting of the Society of Naval Architects and Marine Engineers, held in New York, December 11 and 12, 1913.]

The contract for propelling machinery of the U. S. collier Jupiter was awarded by the Government to the General Electric Company in June, 1911. The designs had been made during the previous year when it was expected that the ship would be built in a private yard. The ship was built at the Mare Island Navy Yard, and was put in commission September 15, 1913. Since that time she has made a number of trial runs in San Francisco Bay and at sea, but she has not yet had her official trials.

The Jupiter is a very large vessel of about 20,000 tons displacement, and is designed to carry about 12,000 tons of coal and oil. The length of her deck over her cargo space is occupied by a line of derricks, which must add considerably to the weight and wind resistance of the ship.

She is a sister ship of the colliers Cyclops and Neptune. The Cyclops was equipped with reciprocating engines and has been in operation for some years. The Neptune was equipped with turbines connected to the propellers by helical gearing.

The Jupiter is equipped with one turbine generating unit and two induction motors, one driving each of the propeller shafts. There is also a board carrying switches and instruments.

A comparison of the equipment of these three vessels is given by the following table:

	Cyclops.	Jupiter.	Neptune.
Displacement, tons	20,000	20,000	20,000
I. H. P. at 14 knots	5,600		
Engine or turbine speed at 14 knots..	88 r.p.m.	2,000 r.p.m.	1,250 r.p.m.
Propeller r. p. m. at 14 knots	88	110	135
Weight driving machinery, tons....	280	156	
Character driving machinery	2 triple expansion engines	1 turbo-generator and 2 motors	2 turbines each with gearing
Steam consumption in lb. per s.p.h. hr.	14 (estimated)	11.2 (tested)	
Speed maintained on 48 hr. trial....	14.6 knots	.....	13.9 knots

The character of the apparatus installed in the Jupiter is shown by the accompanying cuts. It is all of a type commonly used in the electrical industry and need not be described in detail here. There is only one feature about the generating unit which is different from the type of units ordinarily used for electrical purposes, that is, that the governor is so designed that it can be set to hold any desired speed through a wide range, the adjustment of the governor being the normal method of speed variation used in this vessel. The ship can also, if desired, be controlled by the throttle, so that the governor is simply a convenience and in no sense a limitation.

The windings of the generator, which carry the alternating current, are on the stationary part and are insulated with non-combustible material. The generator drives its own ventilating air by powerful impellers attached to the ends of the rotor. This air is delivered from the top of the generator through a duct which connects to the space from which the fire-room blowers take their air supply. The heated air from the motors also passes out of the engine room through similar ducts. The revolving parts of motors are connected to water-cooled resistances through collector rings, and means are provided by which these collector rings can be short circuited so that the rotor circuits are closed upon themselves. Such a condition, with the resistances cut out, is the normal state of efficient operation, the resistances being used only for the purpose of giving a large torque in reversing. The vessel can be operated with the resistances continually in circuit. With this connection, the immediate movement of either motor in either direction is very convenient, and this method of operation is normally used in maneuvering in narrow waters or about wharves. The ship can, however, be maneuvered and reversed without the use of the resistance, and while this method has not yet been fully experimented with, it is thought that her reversal, even without the resistance, will be about as effective as that of vessels having existing types of equipment.

Since the Jupiter apparatus was designed, a method of designing induction motors has been developed which will give all the desired characteristics for reversal without the use of external resistance. Such motors will have squirrel-cage rotors, which are of a simpler character than the definite wound rotors now used. While the method of control and operation of the Jupiter is extremely quick and simple, the operations necessary with this new type of motor will be simpler still. With this new method it will be extremely easy to accomplish all the operations of speed control or reversal of either propeller from the bridge if desired.

When the first tests of the Jupiter operation were made she had been lying at the navy yard dock for four months, so that her bottom was in a very foul condition. Her speed in that condition was something like 25 per cent below normal. This produced abnormal electrical conditions, since the low frequency made necessary the use of higher magnetic densities than are desirable. Many of the conditions of these runs were very unfavorable. A large proportion of the crew were green men; in one fire-room watch a large proportion of the fire-room force were seasick. A great deal of boiler compound was used in the boilers, and the priming

was excessive. The condensed water was much discolored by boiler compound, and water was at frequent intervals forced from the valve packings.

The operation of the apparatus during these runs was exactly in accordance with expectations. The turbine ran with a very perfect balance, and ran just as steadily in rough water as in smooth. The governor held its speed perfectly. The lifting of propellers to the surface at no time caused any perceptible speed variation. The only effect of such lifting of propellers was a fall of current on the instruments showing a diminution of power delivered to the propellers. Examination of the turbine after several such runs had been made showed it to be in perfect condition, and free from rust, scale, or dirt.

After this period of preliminary trials, the ship was docked, and since that time she has made a set of standardization runs and a 48-hour unofficial trial with a clean bottom. On this 48-hour trial the ship averaged 14.78 knots, the average power delivered by the generator was 5,000 kw., corresponding to about 6,300 indicated horse-power. The average revolutions of the propeller were 115. The Cyclops in her official 48-hour run made 14.61 knots with an average of 6,705 indicated horse-power.

The power required by the Jupiter in this 48-hour run is somewhat less than would be expected from the Cyclops performances, and the slip of the propellers is also less than was expected. It has been suggested that this difference might, in some degree, be attributable to the fact that in the Jupiter the torque delivered to the propellers is continuous, while with the reciprocating engines the impulses are intermittent. Careful investigation would be necessary to ascertain whether there could be anything in such a theory. It has also been suggested that there would be some advantage in the fact that the Jupiter's propellers were entirely free from racing, but since some of these tests were made in quite smooth water, this could hardly have had any effect. If no advantage is gained through these causes, it would certainly seem that the performance of the Jupiter's propellers is very creditable to Captain Dyson, who designed them.

Through a misunderstanding, the steam pipe on board the Jupiter was made much too small, so that the normal pressure at the turbine cannot be attained. The vessel will not give her best performances until this is corrected, and until an effective separator is put between the boilers and the turbine so that the efficiency of the turbine will not be affected by priming. It is believed that when these changes are made, the Jupiter can, if desired, be operated at a much higher speed than that which has been attained, and that her economy will prove to be far better than that of any vessel afloat.

The steam consumption of the Jupiter turbine and the efficiency of all of her apparatus have been determined by exhaustive tests at Schenectady, and are also accurately known through knowledge of the performances of other similar apparatus. These results are shown by the accompanying curve, and they cannot fail to be accomplished in the ship herself when all conditions are normal.

Since the preliminary trials above mentioned, the Jupiter turbine has been in-

jured through the breaking of a half-inch top bolt, which held the section of stationary buckets used in the first stage of this machine. On account of this trouble her official trial has been postponed, and it is hoped that the steam pipe will be changed and a separator put in before the official trial is made. A section of stationary buckets held by these bolts is the only detachable part in this turbine. Tap bolts are subject to the danger of breaking under such conditions, and we have had trouble with such method of attachment in other turbines. The matter in this case was, however, unfortunately overlooked. The trouble is easily corrected, and the accident has no significant bearing upon the demonstration which this ship has made. While this bolt destroyed all the buckets in the first stage, the turbine was still capable of operation. The turbine was taken apart because it was seen that the economy was not normal. By taking out the bolt which was adrift and clearing the damaged parts which might interfere, the ship could still have been operated indefinitely at normal speed with a very fair economy. Such arrangements could be made in a few hours.

Four years ago I presented my first paper on Electric Ship Propulsion to this Society. A year before that I had designed an equipment for the battleship Wyoming, and a proposal had been made to the Government in which my designs were embodied. Since that time I have submitted several designs to the Government relating to equipments of battleships which have been built. My last design applied to a case like that of the Pennsylvania, and was submitted last spring. My estimates as to the results of this equipment as compared with those which will be accomplished by the equipment which is being put into the battleship Pennsylvania are shown by the following table:

	R. P. M. 21 knots.	H. P. required, 21 knots.	Pounds of steam per hr. turbines alone 21 knots.	Pounds of steam per hr. turbines alone 15 knots.	Weight of driving machinery in tons.
Turbine drive with geared cruising turbines as adopted..	222	31,700	374,000	106,000	749
Turbo-electric drive	160	29,200	305,000	91,000	598

With reasonable allowances for steam required outside of the main turbines, it would appear that this ship, which is provided with twelve boilers, could, with the turbo-electric equipment, operate equally well with ten boilers. If two boilers were omitted, the whole weight saving would be 266 tons.

If my first design for a warship made over four years ago had been accepted by the Navy Department, the vessel produced would have been very greatly superior in respect to economy, reliability, weight, simplicity, and cruising radius to any ship now afloat, and ever since that time my case has been steadily strengthening through the great improvements which have been made in high-speed turbines.

Since the Jupiter has been put in operation, much interest has been aroused among shipowners and shipbuilders, and it is probable that equipments for sev-

eral large vessels will, within a short time, be contracted for. If such a beginning can be made, the practical results accomplished will soon develop great activities.

DISCUSSION.

THE CHAIRMAN:—Will you show on the blackboard what you mean by the efficiency being 68 per cent and 74 per cent. Those are terms not commonly used.

MR. EMMET:—I am referring to the Rankin efficiency; that is, a comparison with the performance of the perfect steam engine.

THE CHAIRMAN:—The actual efficiency of the turbine, as compared with the efficiency of the perfect primary engine, is 74 per cent?

MR. EMMET:—Within that particular range of steam operation.

THE CHAIRMAN:—I thought that was what you meant, and wanted to have it understood. It does not mean the thermal efficiency——

MR. FREDERICK P. PALEN, *Member:*—I wish to ask Mr. Emmet one question, which is probably so easily answered, he has not considered it necessary to mention it. However, it is not clear to my mind exactly how the power is balanced between the generators and motors in cases where the propellers are reversed, slowed down or start up. Is that done electrically, or do the loads balance from the action of the governors?

MR. EMMET:—Variations of speed in the Jupiter are accomplished by variations of the steam admission, as in any other ship. The electric generator and motors simply act as a speed-reducing bond between the turbine and the propellers. Reversal is accomplished by changing the electrical connections so that the generator tends to drive the motors in the opposite direction. After reversing, the motor very rapidly assumes a speed in the opposite direction in proportion to that of the generator, and this speed can be varied by the steam admission. On the Jupiter turbine a governor is used which can be set to hold any desired speed, but this governor simply affords means of maintaining and varying the steam admission as desired.

NAVAL CONSTRUCTOR JOSEPH H. LINNARD, *Member of Council:*—I ask Mr. Emmett if among the few experiments that were made, under the circumstances he mentions on the Jupiter, there was any experimentation on the subject of quickly reversing at full speed, when the vessel is full speed ahead, reversing quickly and going astern. It is known that brings very heavy strains on apparatus of any kind in propelling a ship, and is a pretty severe test of any machinery.

Mr. Ernest H. B. Anderson, *Member:*—This paper is of great interest to marine engineers and shipbuilders, for the reason that a great deal of matter has been written about this system of marine propulsion and this installation is the pioneer of its kind in this country.

It is rather disappointing that the official trial results are not available, and that the difficulties which interfered with these trials appear to have been largely due to faults in the generating unit and not in the motive power driving the propellers, which is the real novelty of this installation.

In connection with the preliminary trials, I should like to know if the vessel was fully loaded to the designed draught, and the corresponding displacement of 20,000 tons.

The test of the steam consumption per shaft horse-power for the turbine is exceptionally good, but I think this result was obtained whilst the machine was under test on shore and not during any preliminary sea trials.

It is, however, in no way a conclusive argument as a comparison with a sister ship having another type of machinery, for the reason that the shaft horse-power upon which the figure was based is not given, but I believe the original design called for an estimated shaft horse-power of 7,000 at 14 knots speed of the vessel.

The estimates Mr. Emmet puts forward for an electrical installation in a battleship similar to the Pennsylvania are interesting, but I do not see how he can justify himself in publishing such figures until he has shown just what the system is capable of in the Jupiter.

With regard to the second last paragraph of this paper, I trust the author will see his way to withdraw it completely, for I consider it does not seem right that such a statement should be made in the Proceedings of this Society.

It seems to me that the Navy Department, and especially the Bureau of Steam Engineering, have given Mr. Emmet and his colleagues a splendid opportunity of proving their claims, and it is up to these gentlemen to make good and not belittle the marine engineers of the Navy, who are forced to listen to all kinds of propositions submitted for their consideration.

It is not my purpose or wish at this time to put forward any claims or advantages for other systems of propulsion, but solely to show the members of this Society that I consider the Navy Department has given Mr. Emmet every assistance in making his system a success.

In Great Britain a company has been formed, consisting of the leading electric engineers and one or two shipbuilders, and they have built and equipped a small cargo ship at their own expense, and I feel certain they have not had the assistance of the government financially. As you all probably know, I refer to the Tynemount, which has propelling machinery somewhat similar to that under discussion, and for a complete description and various criticisms of this interesting vessel I refer you to the *Engineer*, October 10 and 17, and also to many of the other technical journals published in Great Britain during the last two months.

In regard to the Jupiter, the November number of the Journal of the American Society of Naval Engineers contains a very full account of this ship, giving complete particulars of the generator and turbine, the motors, and many details of the ship.

Mr. Edwin A. Stevens, Jr., *Member:*—I would like to back up what Mr. Anderson says about the ability of the engineers in the United States Navy. Although not connected with the service in any way, I was, however, in the Naval Militia as an engineer officer and came in contact with a number of the naval officers; my respect for them as engineers is very high,

and I think that the statement which Mr. Emmet has made, in the next to the last paragraph of his paper, is very broad. He says: "If my first design for a warship made over four years ago had been accepted by the Navy Department, the vessel produced would have been very greatly superior in respect to economy, reliability, weight, simplicity and cruising radius to any ship now afloat, and ever since that time my case has been steadily strengthening through the great improvements which have been made in high-speed turbines." In regard to economy we can rely, to some extent, upon certain calculations, although we do know that calculations sometimes go astray. In regard to weight, the same thing applies there. In simplicity, he might or might not be right; it depends whether marine engineers want a lot of electrical devices to bother with. There are lots of men who succeed in the mechanical line who do not seem able to grasp electrical engineering.

In regard to reliability, I am surprised that a man of Mr. Emmet's ability and experience should make a statement of that character. In my short and limited experience, compared with that of Mr. Emmet, I have found that reliability is something that we can tell very little about until we have actually tried the machine in practice. I cannot understand Mr. Emmet making such a statement. He might have reason to believe so, but that will not make it more reliable in practice.

In regard to economy, I do not think there is very much question but that the combination of the reciprocating engine exhausting into a turbine is the most economical unit; the turbine might be geared to its propeller shaft so as to get as high propulsive efficiency as possible.

Mr. Emmet talks about putting all the reciprocating engine builders down and out. All I have to say to that is this—he has not done so, nor do I think he will. The reciprocating engine has not been perfected, and I do not think it will be for a great while—improvements are being made on it all the time.

Between the years 1896 and 1905 very little improvement had been made in the economy of the reciprocating engine, except that due to the use of higher pressure of steam. No attempt was made to decrease the clearances, to straighten the steam passages, etc., until about the end of the above-stated time; in fact in some cases the ships that were built at the latter part of this time had greater clearances than the earlier ones; for instance the gunboat Marietta (built in 1896) had about 16 to 17 per cent clearance in the high-pressure cylinder, while the armored cruisers Washington and Montana (built about 1906) had about 28 per cent.

When the Michigan and South Carolina were built some attention was given to cutting down the steam consumption. In these engines the valve chests were lengthened, thus cutting down the clearances and making straight steam passages instead of crooked ones. The steam pressure was higher, and the range of expansion was greater, than in any previous battleship. While there are no data on steam consumption of these two ships available, it is safe to state (judging from their coal consumption) that these engines were greatly superior to any battleship engines that had been built up to that time.

The Delaware (which was completed shortly after the above-named ships) had engines very similar to the Michigan. On the full-speed trial the water consumption was a little over 13 pounds per indicated horse-power per hour, while at 19 knots it was slightly under 13 pounds.

Lieutenant-Commander Dinger estimates that in the combined system the water rate can be cut down to 8.5 pounds per horse-power per hour. He takes as a basis for his estimates two ships already built and tried. In the Delaware the steam pressure carried in the

low-pressure receiver was about the same as that at the low-pressure turbines of the Utah. Taking the water rate of the Delaware engines for the high and intermediate pressure cylinders, also the water rate for the low-pressure turbine of the Utah, and combining the two, he gets an economy of about 9.5 pounds of water per horse-power per hour, which is about as good as can be expected under present practice. He also states that still further improvements can be made which would bring the rate down.

In closing I would like to say that if the same attention had been given to reciprocating engines as has been given to turbines there is no doubt but that this type of engine would be a great improvement over those now in use.

THE CHAIRMAN:—Is there any other gentleman who desires to discuss the paper before Mr. Emmet replies?

COMMANDER J. K. ROBISON, U. S. NAVY, *Visitor:*—As an engineer officer in the Navy, I want to say that we subscribe heartily to what Mr. Emmet says. There is not one of us who will ever know as much about the Jupiter as he does. I do not think that there is any use of our knowing so much as that. As he says, ours is not a case of not wanting advantages, but it is our principal duty to get things done for us. He says he does not quite understand—I do not think he put it that way exactly—the extreme conservatism of the naval engineer. And I will point out that they have not electrical turbines on locomotives as yet. There is one paragraph in his article as printed, that, it seems to me, indicates somewhat difficulties that we do not yet know anything about, and that we must know before we can subscribe heartily to Mr. Emmet's opinion as stated in the article, and admit the certainty that his scheme is always going to be better than anything else. For instance, this collier is sometimes going to have 10,000 tons of coal in it and sometimes not any. What will be the effect of that on your electrical density? What effect will that have on the operation of the motors? Suppose the governor—which is a wonderful governor, and which is completely automatic—does not always function? Suppose it happens to work like the automatic water level regulator on the Belleville boiler? Suppose you have a ship pitching heavily, will that affect your motors at all? As pertaining to our alleged ultra conservatism, we would like to invite the attention of the author, who has done so much for us, to the fact that the Jupiter is a naval collier, and I do not think there are any other vessels equipped with this plan of propulsion.

THE CHAIRMAN:—I do not want to shut off the discussion if there is any one who desires to speak. If no one else desires to discuss the paper, we will ask Mr. Emmet to make such replies as he cares to.

MR. EMMET:—Mr. Linnard put the question about reversibility. I saw the ship reverse. She was going about three-quarter speed, possibly, the switch was simply thrown, there was no experiment made to determine time, etc. I do not think there would be many strains, except what might come on the propeller blades, and the conditions are not essentially different from those of any other ship in that respect. At least I can see no reasons for there being any difference.

The question of the relative efficiency of turbines and engines is one that we do not need to discuss here at very much length, because it has been so much talked about, but there are certain underlying reasons why a turbine should be more efficient. It can provide

for the full expansion of the steam and full available energy in the low-pressure ranges, whereas no steam engine can do so. By going from non-condensing to condensing on steam engines the gain is something like 30 per cent, and going from non-condensing to condensing on turbines the gain is more than 100 per cent. There is every reason why the steam engine is necessarily inefficient in low-pressure ranges; that is one reason why the turbines have been introduced, and while certain refinements will improve reciprocating engines, the history of the art would seem to indicate that the reciprocating engine, for all purposes to which turbines are now used, has been virtually given up.

What I said about knowledge of the Jupiter was not intended as a reflection on the Navy at all, but simply intended to imply that there is no possibility of studying that unit on board ship as it was studied in Schenectady, because we made particularly careful and analytical study of it, in which tests we could vary the speed and load, and trace curves of all possible variations, of speed, load, pressure, vacuum and superheat. It was the first turbine of the type which we produced. We first built a turbine of an earlier type, for the Jupiter, and got permission from the government to rebuild it, because it gave us the first, easiest, and quickest opportunity of getting information about the performance of this new type. Having done so, we wanted to investigate its action thoroughly.

As to the possible failure of the governor on the Jupiter which Commander Robison has mentioned, it would have no more effect than if you had a governor on some other ship and took it off; the Jupiter is not dependent on the governor. There is a hand-operated throttle valve and there is an emergency stop. We use a type of valve which has a tendency to be closed by the steam. It is a reliable means of stopping, so that the governor could be entirely left out and the ship still be safely and well operated.

The question of operation at light load would only simplify the electrical problem, because you have less load on the turbine. The turbine will run at any speed assigned to it, at the load which may result.

With reference to the paragraph in the paper which has been criticised, and with regard to what I have said, I want to explain that there is no one who has more respect for the engineers of the Navy and naval officers generally than I. I used to be in the Navy myself, and some of these men I have criticised I am very fond of. The only view which, in my opinion, should be taken of a paragraph of this sort is that it is simply a statement of opinion. It does not read to me like an indictment of anybody. I think I have very good reasons for all these various items as mentioned in that paragraph. I also think that some of the engineer officers of the Navy have not investigated these points as they should have done. I have invited them to investigate them, but there has not been a man sent to Schenectady to investigate electrical propulsion. There was a man detailed to report it. Two naval officers have been stationed in Schenectady and had an opportunity to talk with me from time to time on this subject. One was Commander McNamee and the other Lieutenant Foote, who is there now. Both have become very enthusiastic about my designs for warships. I was told by a friend of mine that he had heard it said in the Navy Department that whenever any officers went to Schenectady they got crazy on the subject of electrical propulsion, and I suppose that is the reason why more do not come there.

There is a great deal in what I have been saying which is easily the subject of analysis and investigation. I have done an immense amount of work on this subject and am doing it simply as a matter of engineering interest. I have other kinds of important engineering work to do, and there is nothing I want to do so little as to lose my reputation as a successful en-

gineer. I have a great deal more at stake than any of these naval officers have. (Laughter.) If the machine fails, it is not their fault; they would not be blamed, but it would be highly discreditable to me.

There is a great deal in this subject which by study and analysis can be verified. I pointed out, when I first came before this Society, that we had had two fire-boats operating in Chicago for a couple of years then. They have much more complicated electrical apparatus on them than these big ships would have. They are absolutely neglected, as far as the electrical details are concerned, treated in the roughest way imaginable, and they are never subject to any electrical trouble.

I am perfectly justified in all the statements I make about reliability and efficiency, because they are matters of general knowledge and matters applying to every industry except the propulsion of ships. And the Jupiter, furthermore, has demonstrated and is demonstrating them. Mr. Anderson speaks of the troubles in the turbine—there has been one little bolt that broke loose, unfortunately, before the ship was ready to run. They did not stop her until they heard a noise, and finding trouble they naturally stopped the trial trip. One hour's work would have put the turbine in shape to make nine-tenths of her regular speed, if not the whole; there was nothing vital broken, but this object had dented the buckets in one stage. Since the Jupiter has been standing at the Mare Island Navy Yard, ready to run, older and, I think, inferior methods of propulsion have been adopted in two battleships, and I am of the opinion that the Navy is making a mistake in not making further effort to expedite a knowledge of this thing, and to realize its importance. Most other branches of engineering do realize the importance of the high-speed turbine.

I will make my statement broad enough to cover the gearing as well as the electrical propulsion, because I have great faith in the possibilities of gearing. Sir Charles Parsons has designed a great many ships, and they have all been successful, so far as I know, and I think they will be, because everything the man has done has been successful. He is a very great man. As I understand it, Mr. Parsons had a ship ready to run before they began to talk about gearing for ships in this country.

The Chairman:—I beg your pardon—that is not correct. They had begun to build the first experimental gearing at the Westinghouse works before the Vespasian was fitted up.

Mr. Emmet:—It does not make much difference. Everybody who has made any high-speed gearings is entitled to great credit. Such gears are not only used in ships, but on shore. The Westinghouse Company has two big machines in Cleveland working successfully with such gears. The reason for both methods is the great merit of the high-speed turbine, and it is a plea for the high-speed turbine that I am making.

The Chairman:—I am sure you will all desire me to express the thanks of the Society to Mr. Emmet, which I will be glad to do.

Mr. Francis T. Bowles, *Past President:*—I move a vote of thanks to Mr. Emmet for his excellent paper and that we extend to him our compliments for the excellent temper which he has shown in the discussion.

The motion was seconded, put to vote and duly carried.

Vote of Thanks to the Presiding Officer.

Mr. Francis T. Bowles, *Past President:*—Mr. Chairman and gentlemen, with your permission I will call the attention of the Society to the fact that, owing to the regrettable illness of our President, the Executive Committee was obliged, on very short notice, to draft our Vice-President, Mr. McFarland, to act as presiding officer at this meeting, and also to take charge of the banquet this evening; and therefore, if you will permit me to usurp his functions for a moment, I propose a cordial vote of thanks to him for the excellent manner in which he has presided over the deliberations of our meetings, and ask him to convey to the President our regret at the cause of his absence, and our hopes for his good health. All those in favor of the motion, please say Aye; contrary-minded, No. The motion is unanimously carried.

Mr. W. M. McFarland, *Vice-President:*—I thank you all very heartily, and wish to express my own cordial appreciation of the kindness with which you have treated me in my attempt to fill the office of presiding officer during the meeting.

The meeting is now adjourned until the banquet this evening at the Waldorf-Astoria Hotel.

Deaths, 1913.

Edwin S. Alexander.

Walter Ancker.

Albert W. Butler.

Thomas F. Carter.

Charles H. Cramp.

Edwin S. Cramp.

Henry F. Donaldson.

William H. Fletcher.

Robert Forsyth.

Frank D. Hall.

Valdemar F. Lassoe.

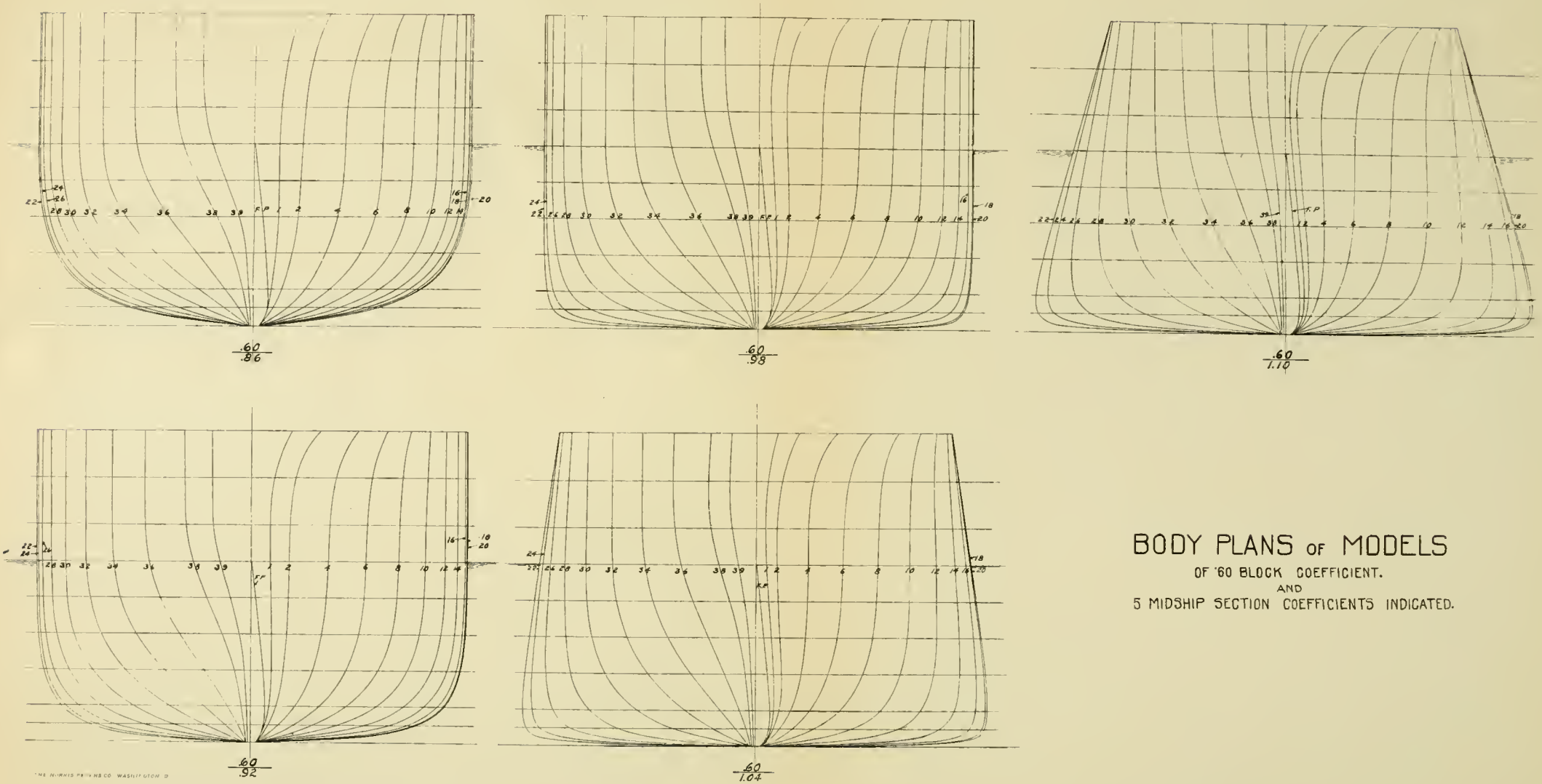
George W. Quintard.

Anson Phelps Stokes.

Aaron Vanderbilt.

Sir William H. White.

To illustrate paper on "Relative Resistance of Some Models with Block Coefficient Constant and Other Coefficients Varied," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



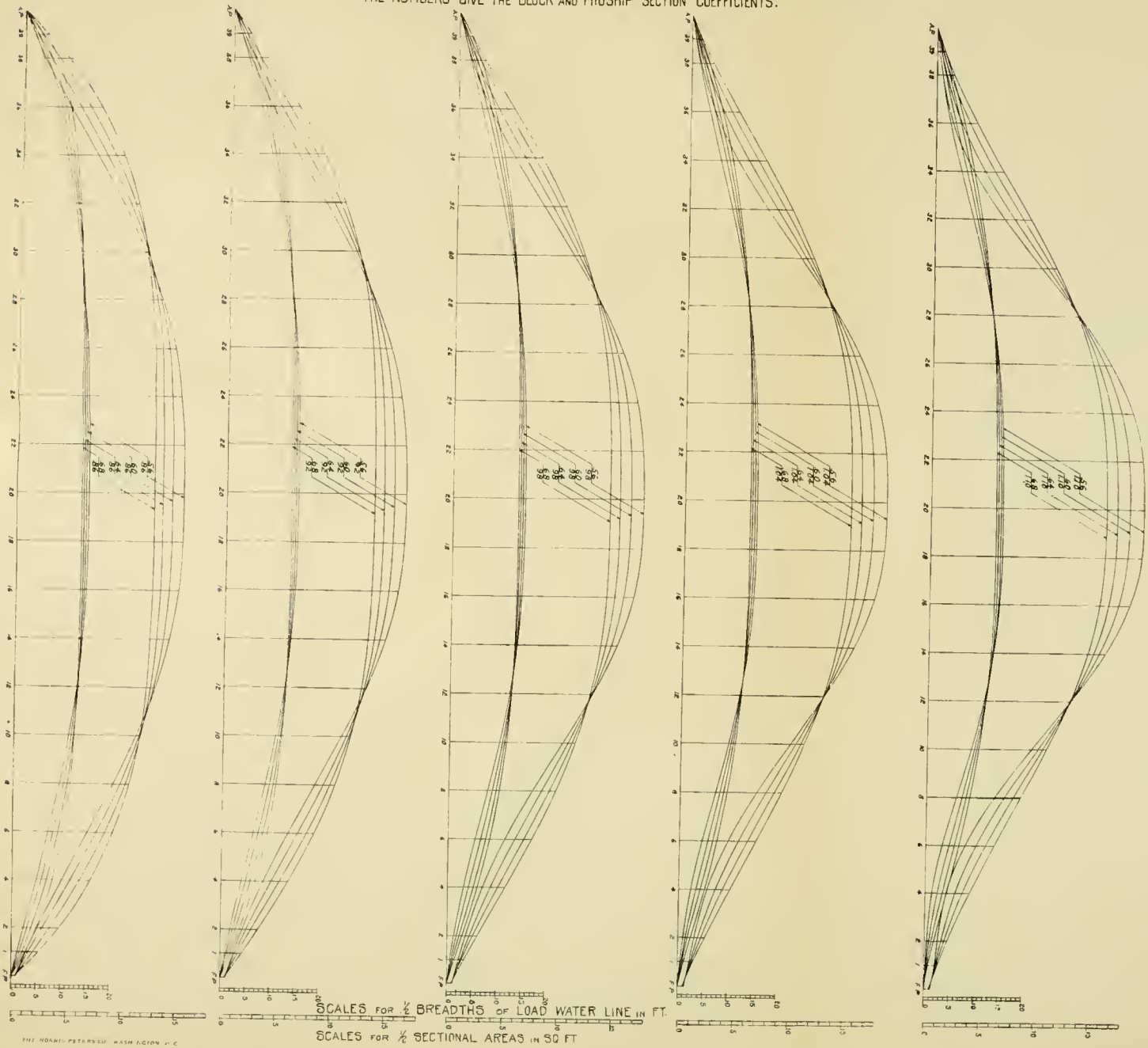
BODY PLANS OF MODELS
OF .60 BLOCK COEFFICIENT.
AND
5 MIDSHIP SECTION COEFFICIENTS INDICATED.

THE NORRIS PRINTING CO WASHINGTON D

To illustrate paper on "Relative Resistance of Some Models with Block Coefficient Constant and Other Coefficients Varied," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

WATER LINES AND SECTIONAL AREA CURVES FOR THE 20 MODELS.

THE NUMBERS GIVE THE BLOCK AND MIDSHIP SECTION COEFFICIENTS.



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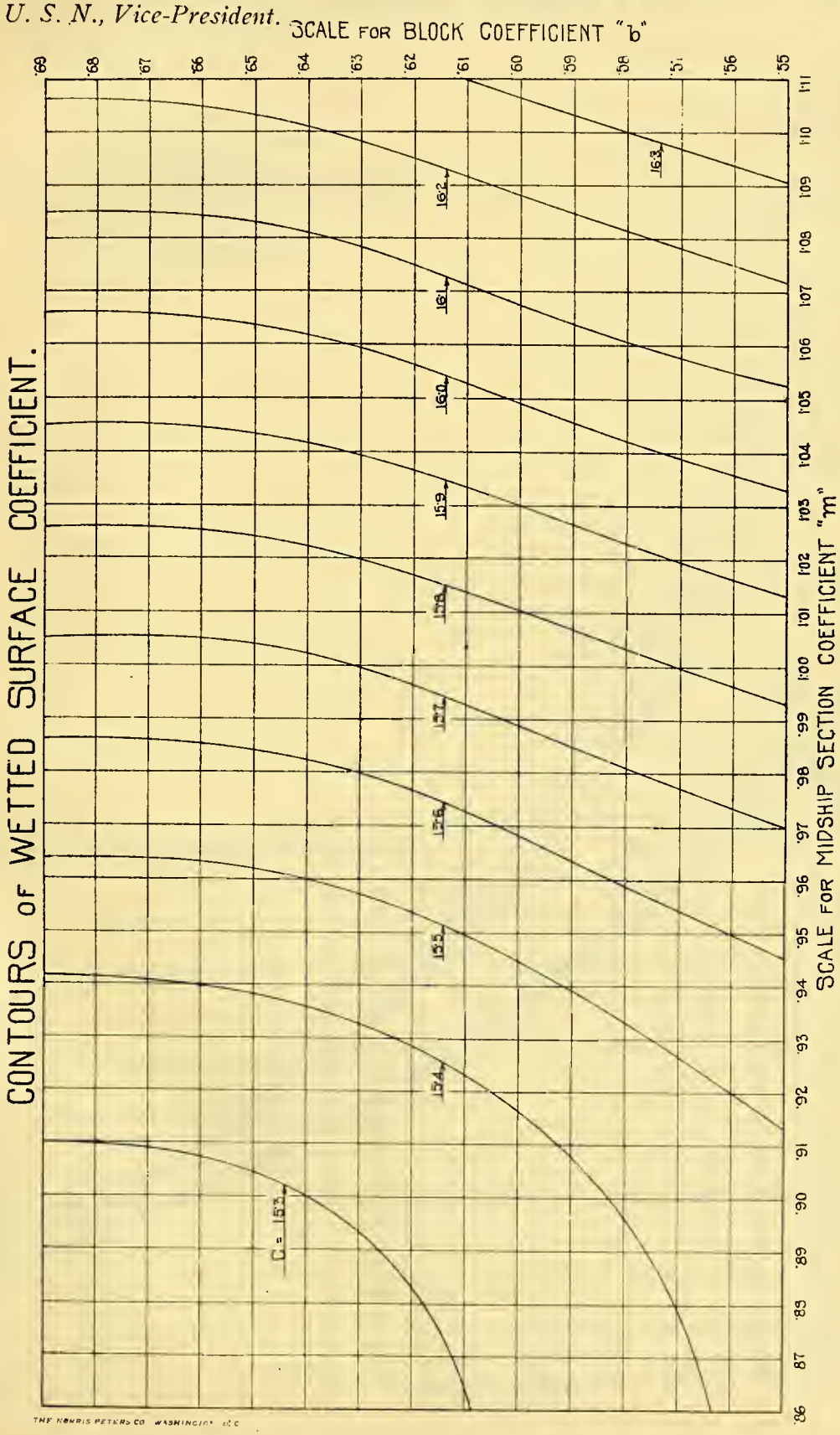

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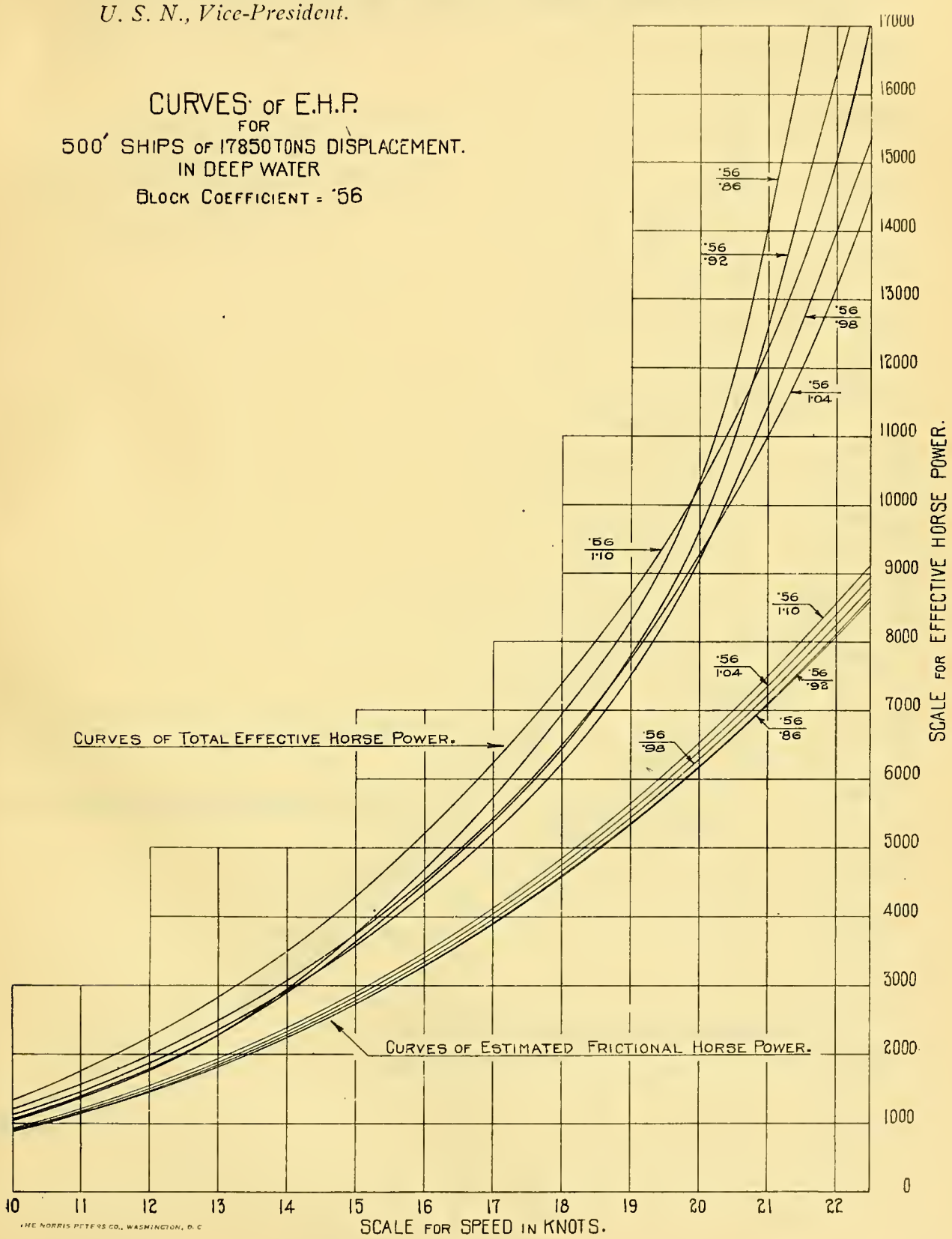

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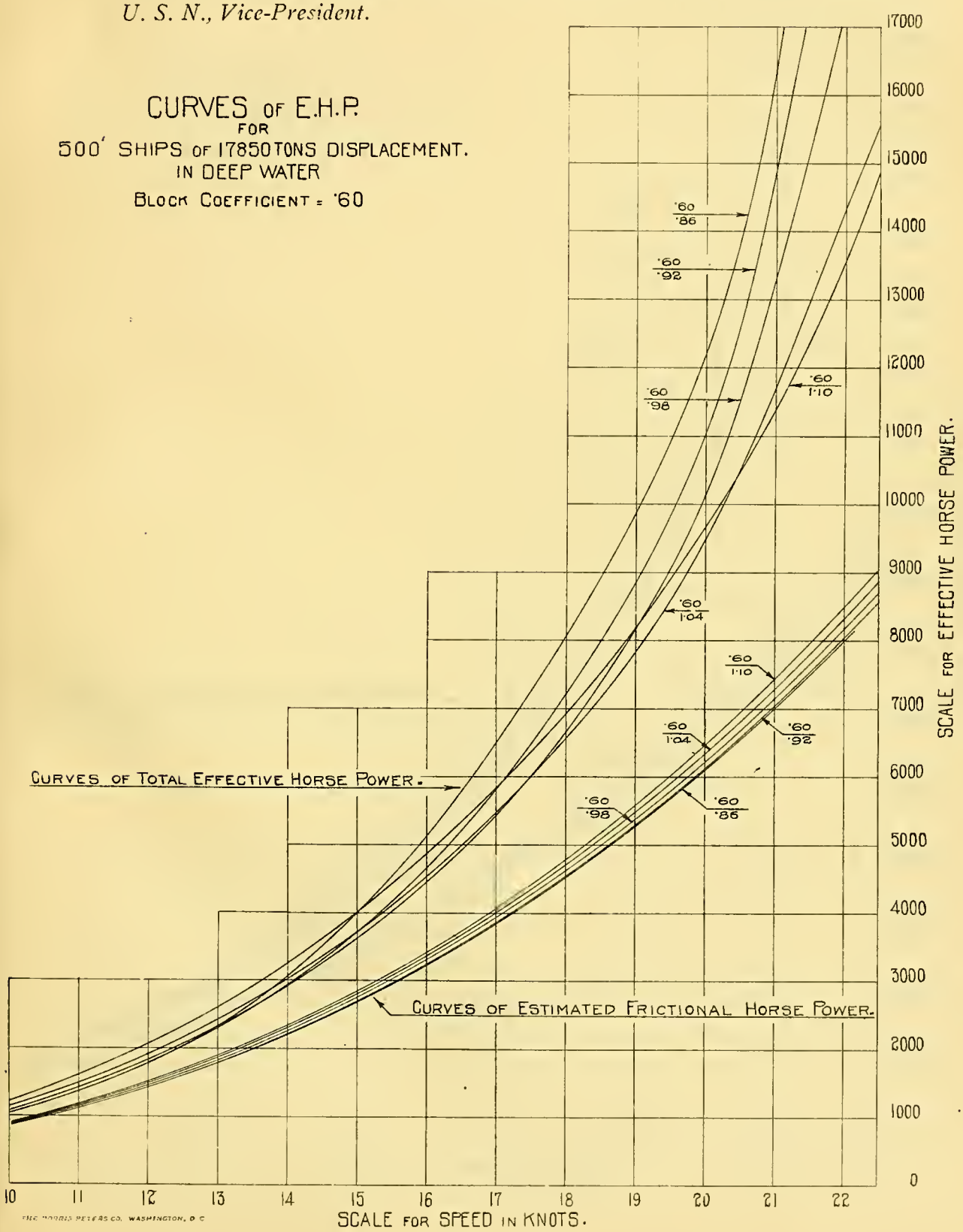

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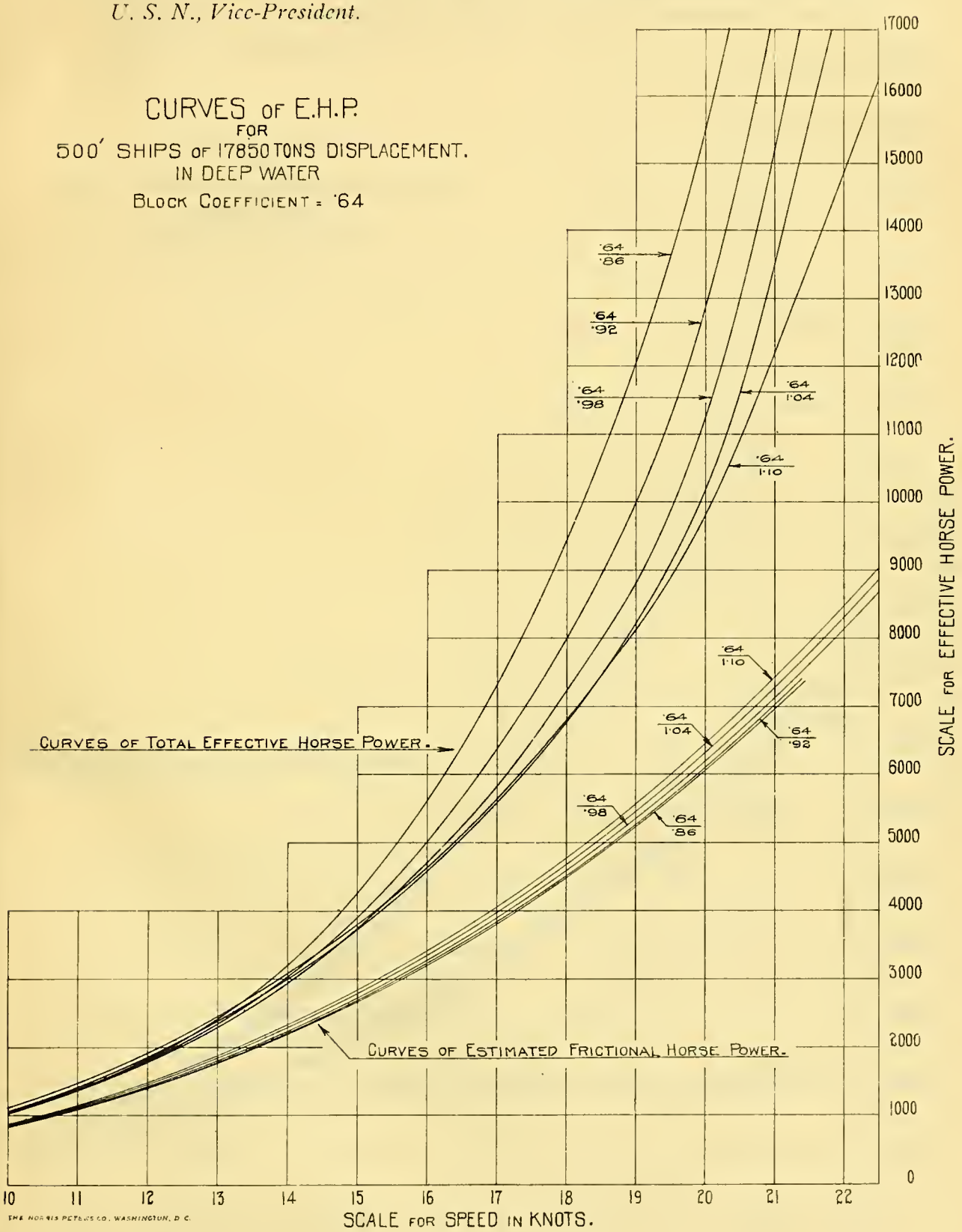

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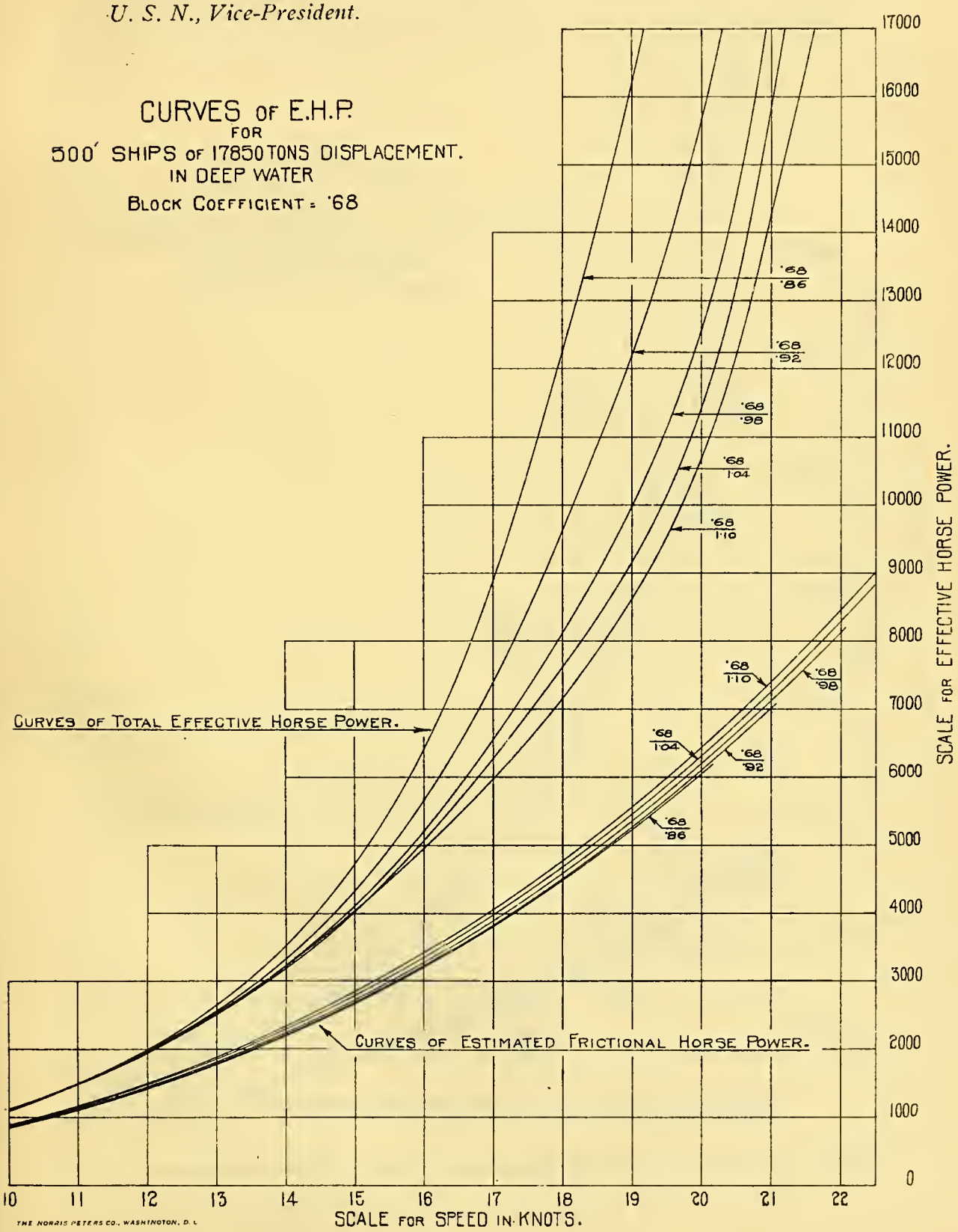

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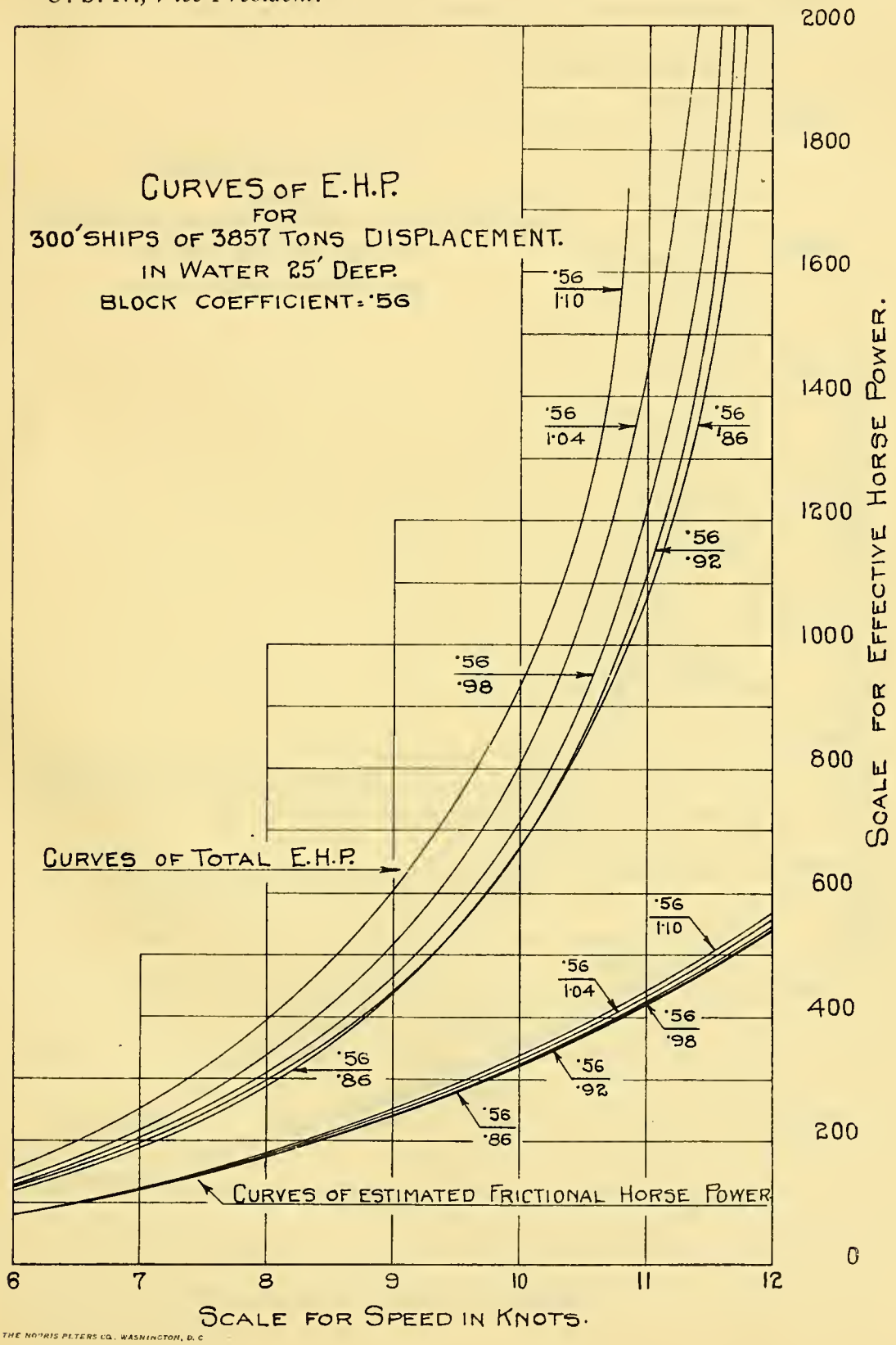

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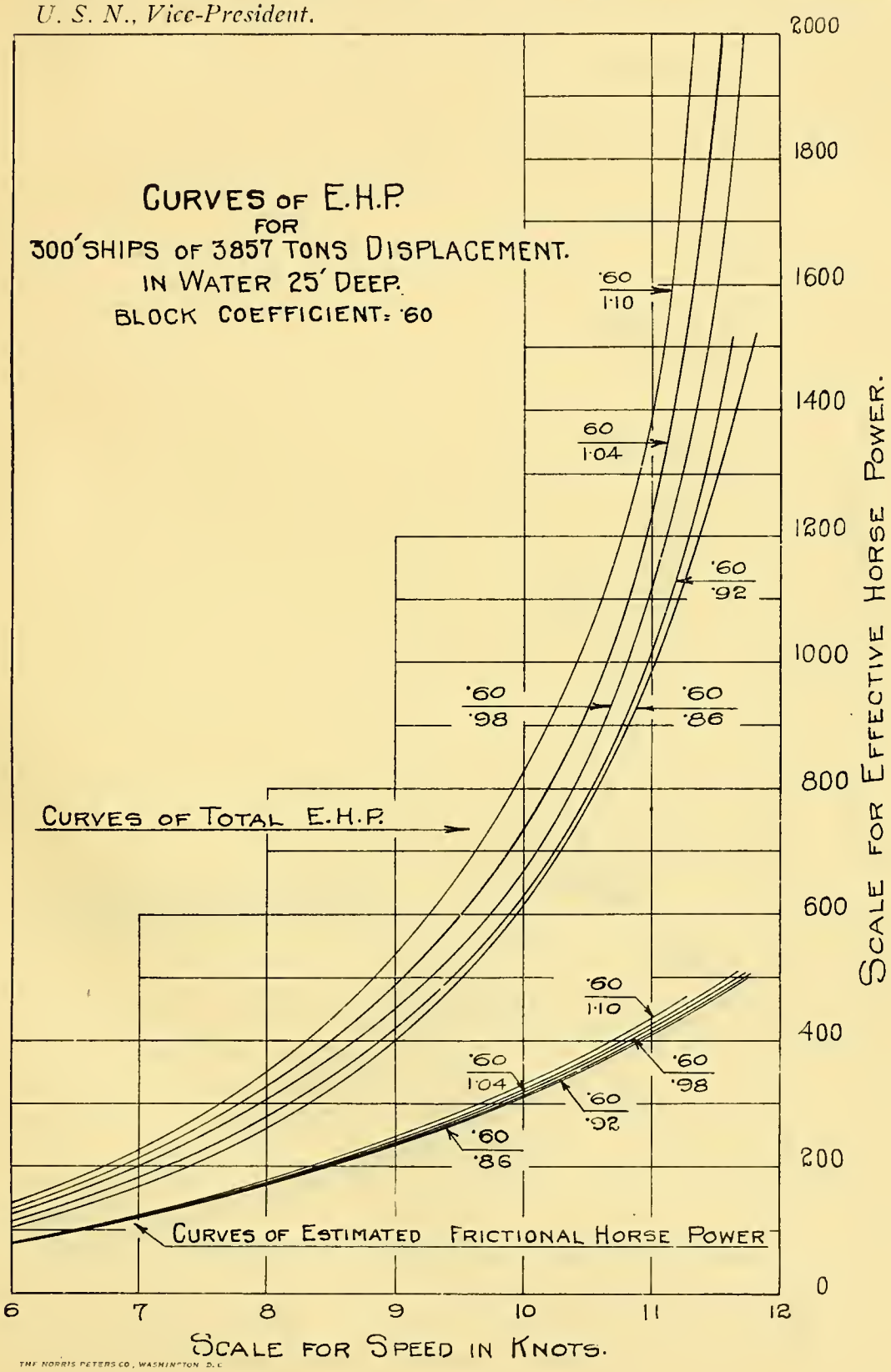

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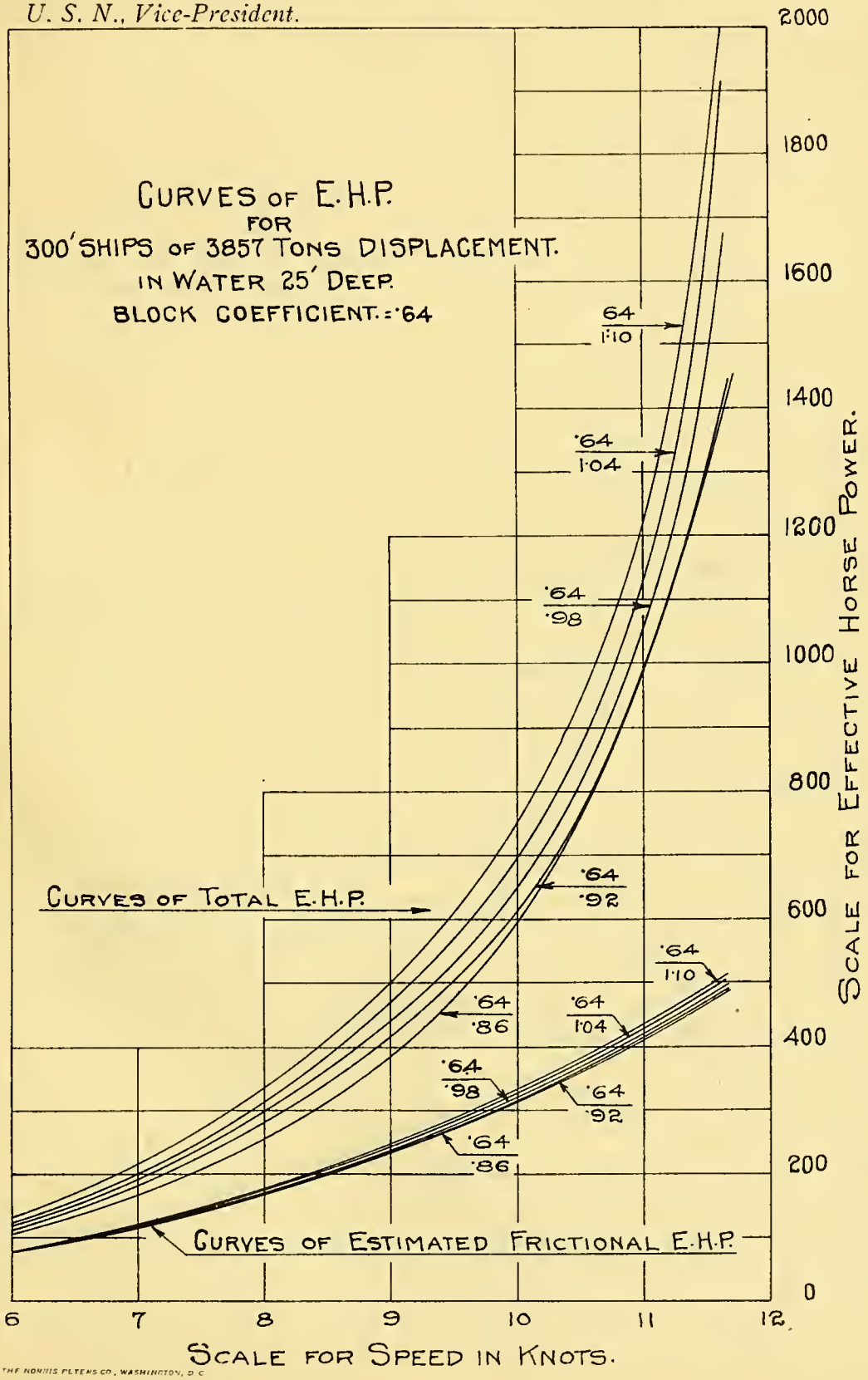

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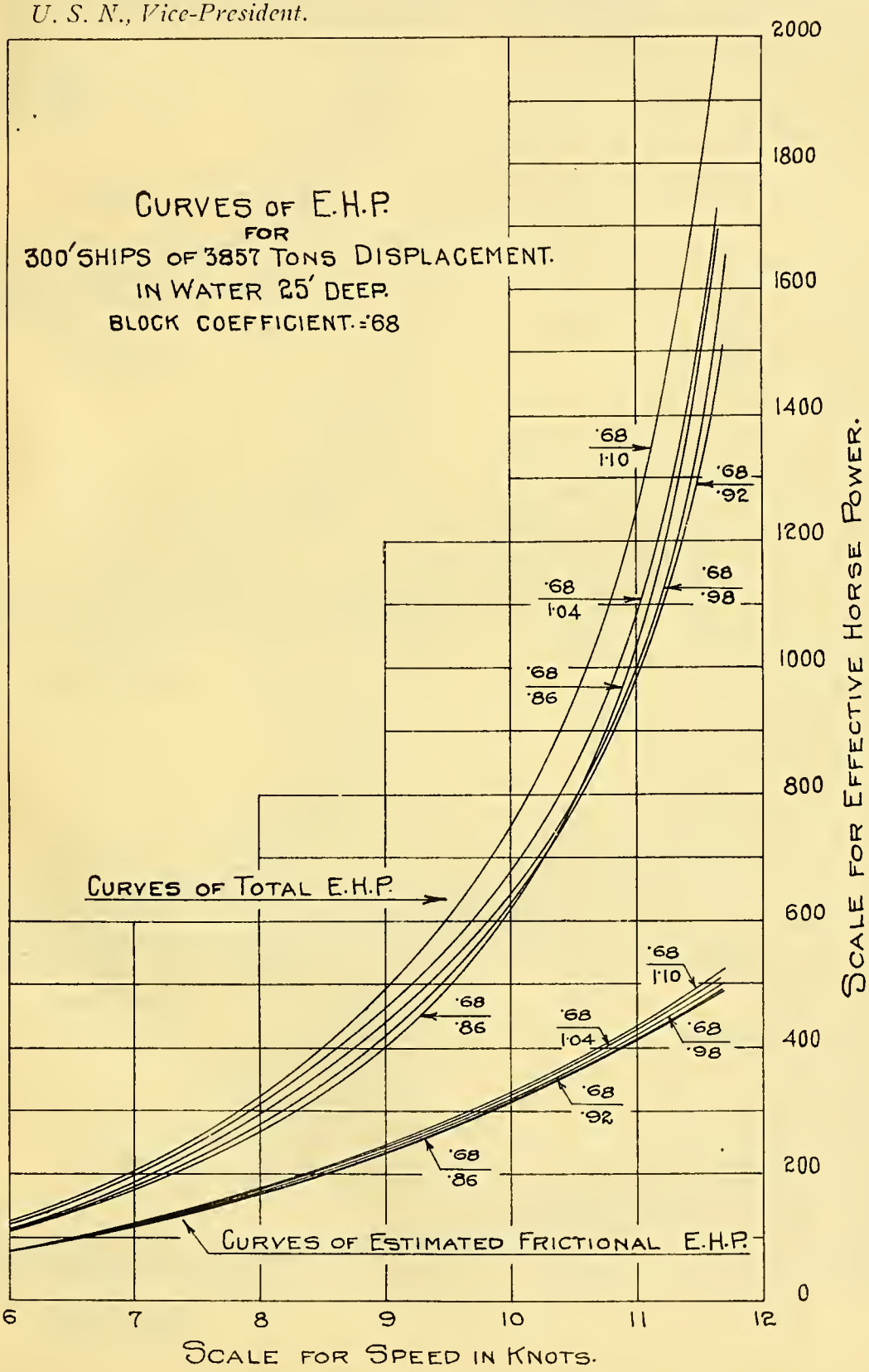
To illustrate paper on "Relative Resistances of Some Models with Block Coefficient Constant and Other Coefficients Varied," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



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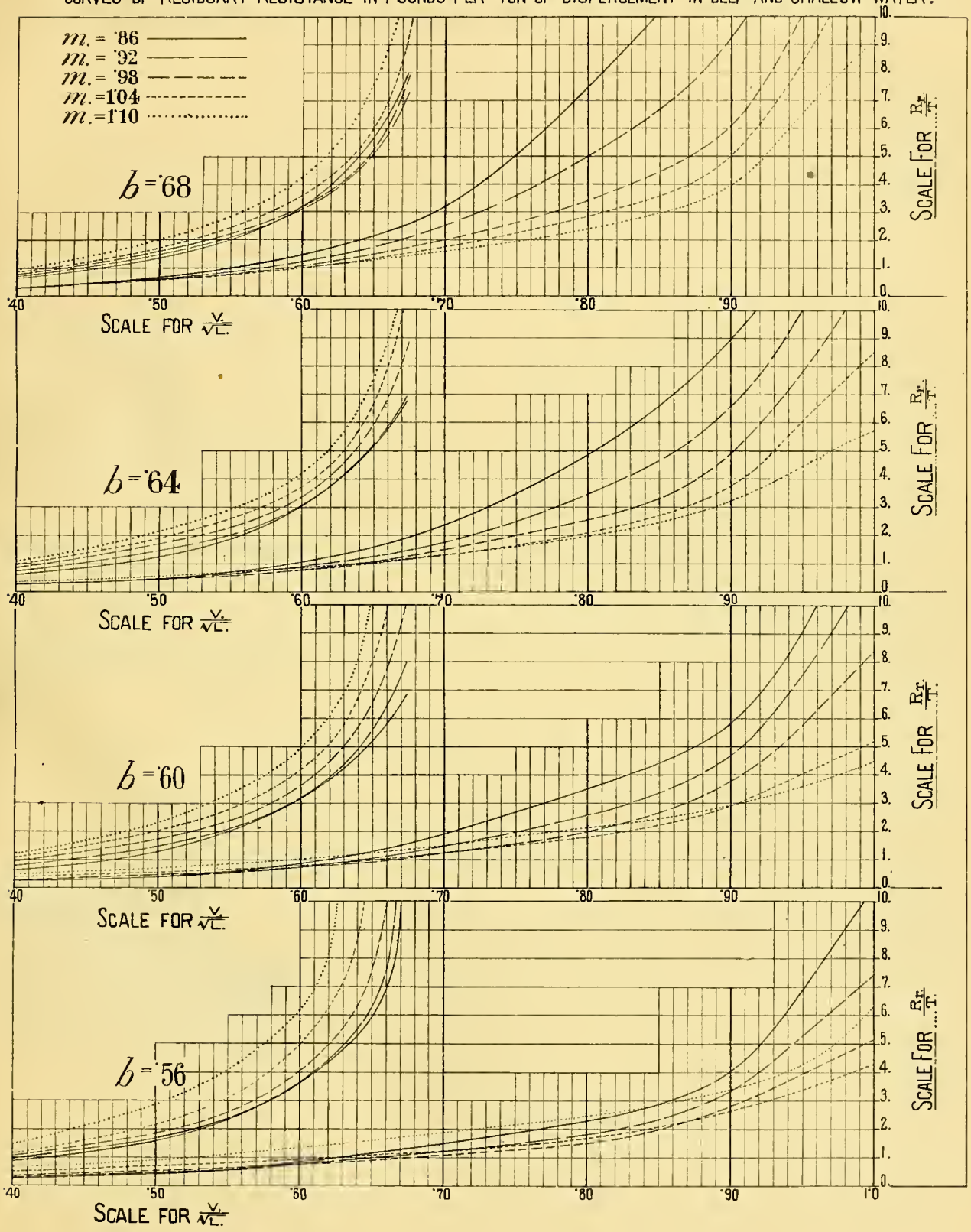
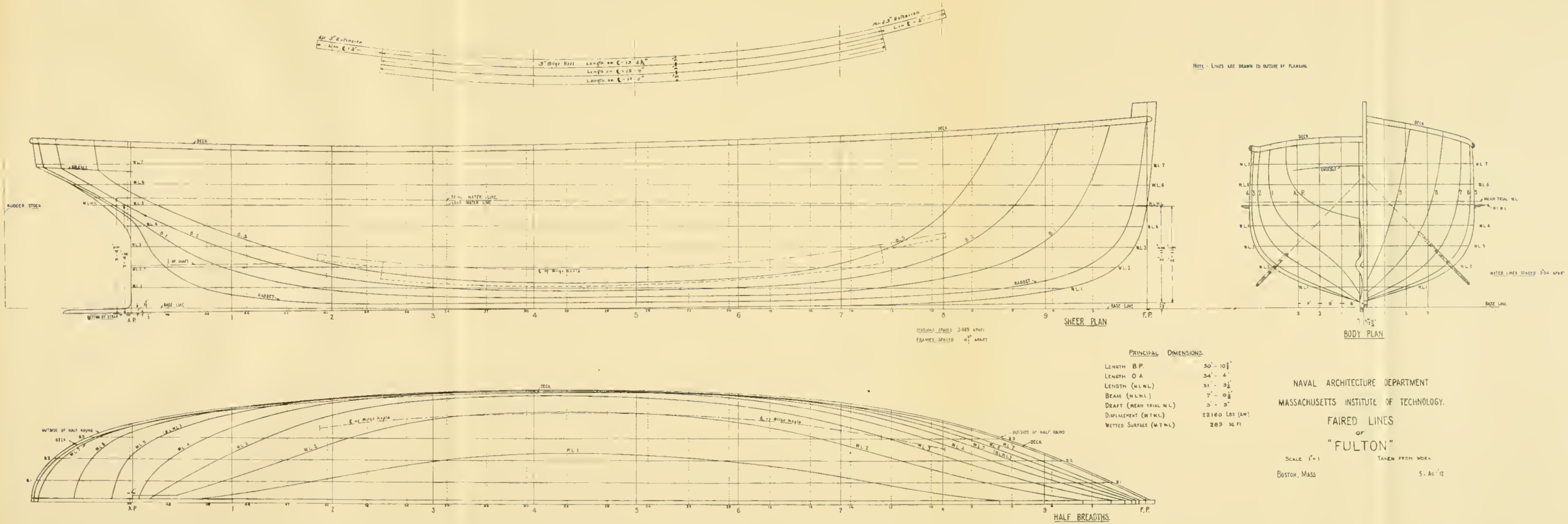
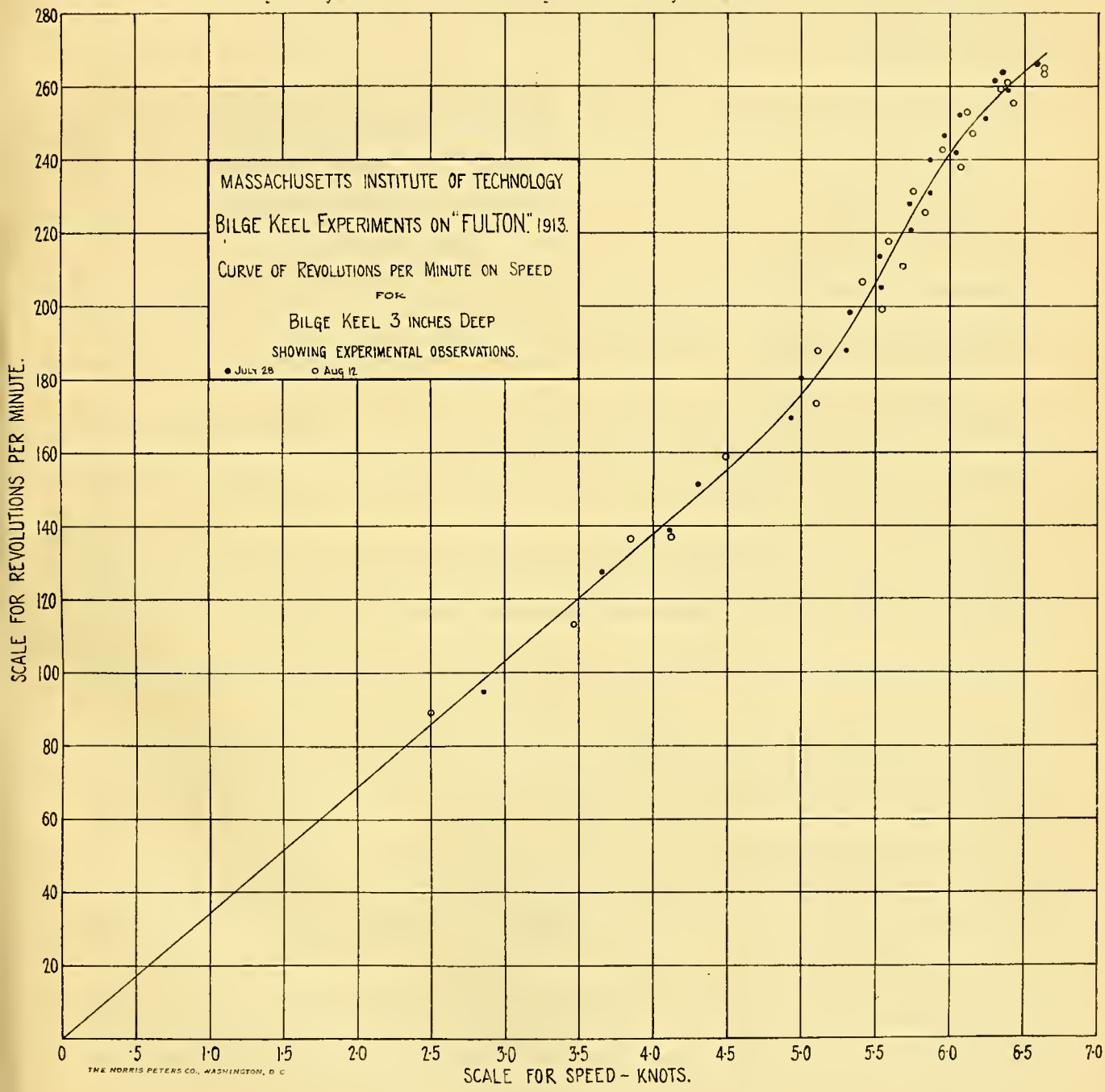
To illustrate paper on "Relative Resistance of Some Models with Block Coefficient Constant and Other Coefficients Varied," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

CURVES OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT IN DEEP AND SHALLOW WATER.




SHEER PLAN
BODY PLAN
HALF BREADTHS
PRINCIPAL DIMENSIONS.
LENGTH B.P. 30' - 10 1/2"
LENGTH O.A. 34' - 4"
LENGTH (W.L.W.L.) 31' - 3 1/2"
BEAM (W.L.W.L.) 7' - 0 1/2"
DRAFT (MEAN TRIAL W.L.) 3' - 3"
DISPLACEMENT (W.T.W.L.) 22160 LBS (SW)
WETTED SURFACE (W.T.W.L.) 289 SQ FT
NAVAL ARCHITECTURE DEPARTMENT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
FAIRED LINES
OF
"FULTON"
SCALE 1" = 1'
TAKEN FROM WORK
BOSTON, MASS
5. AG. '12

To illustrate paper on "Resistance of Bilge Keels," by Professor C. H. Peabody, Member of Council.



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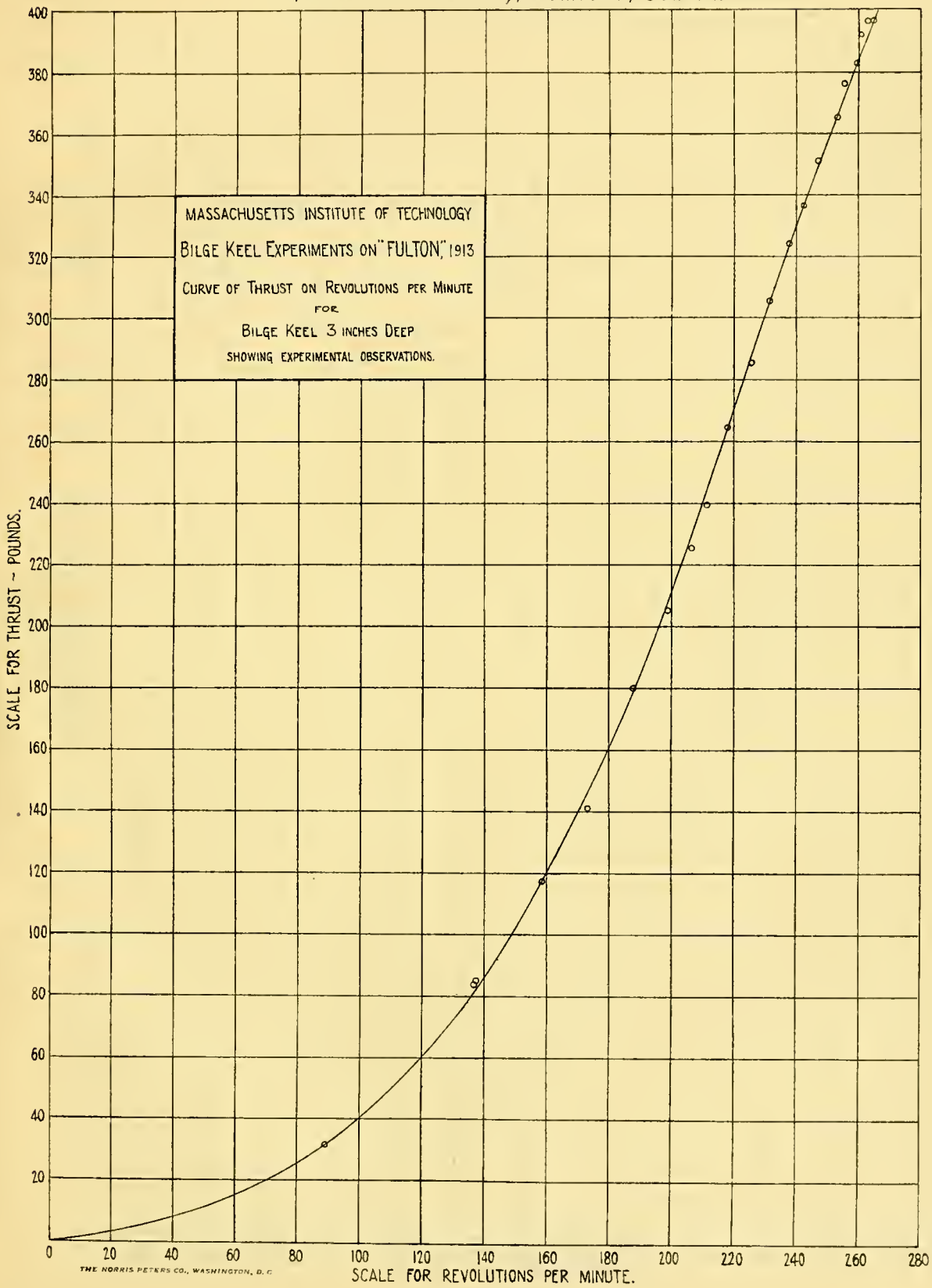

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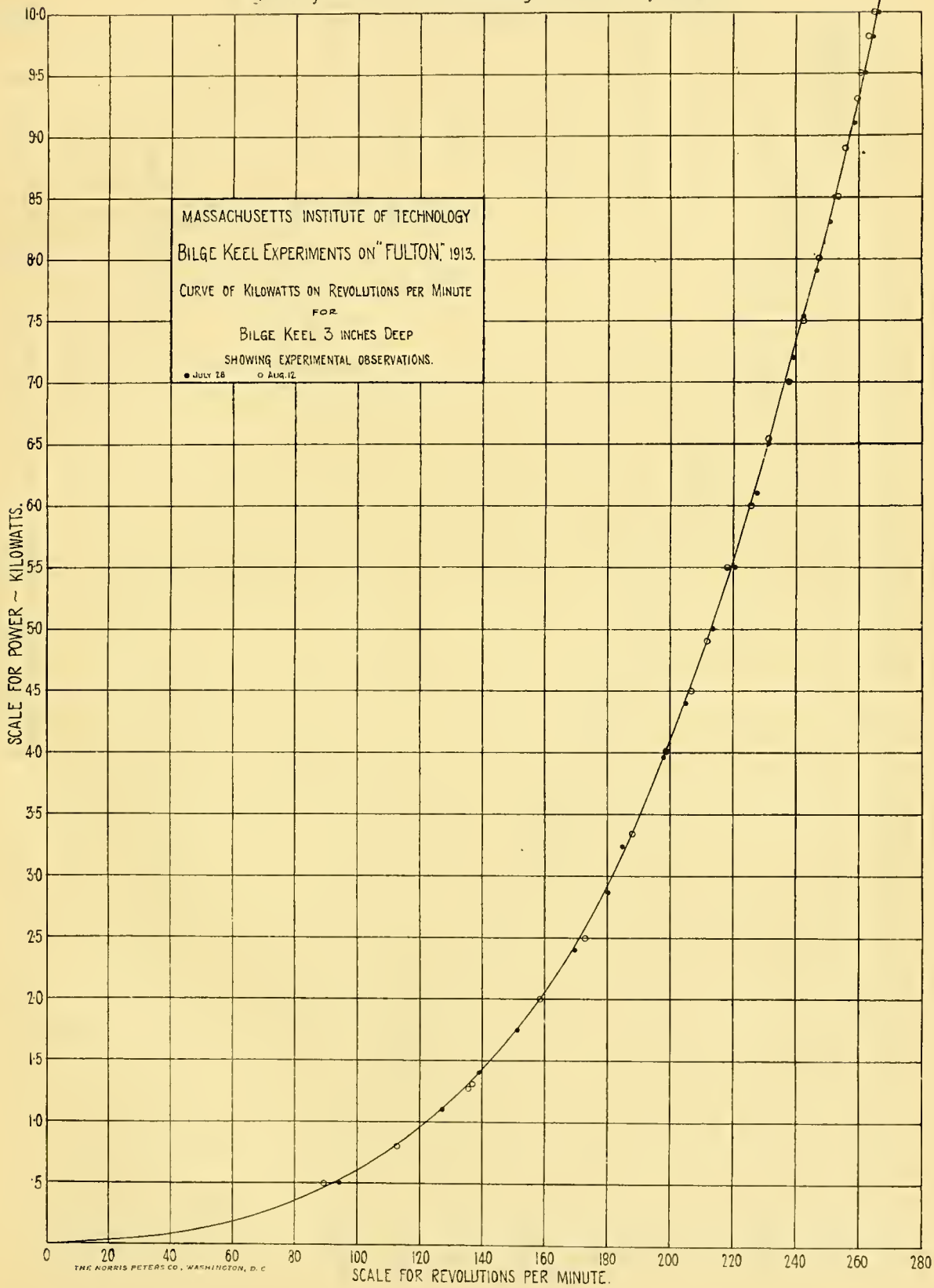

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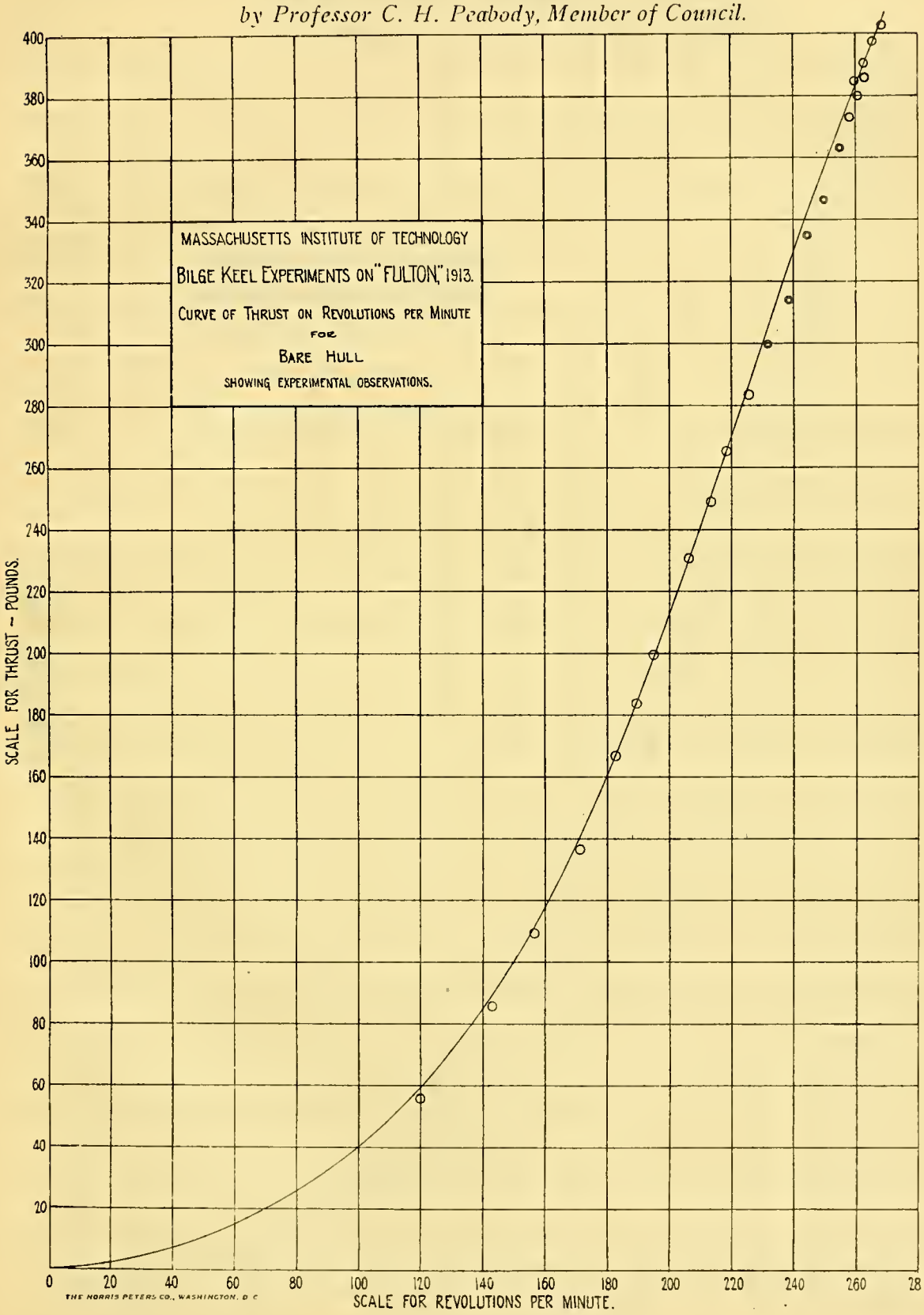

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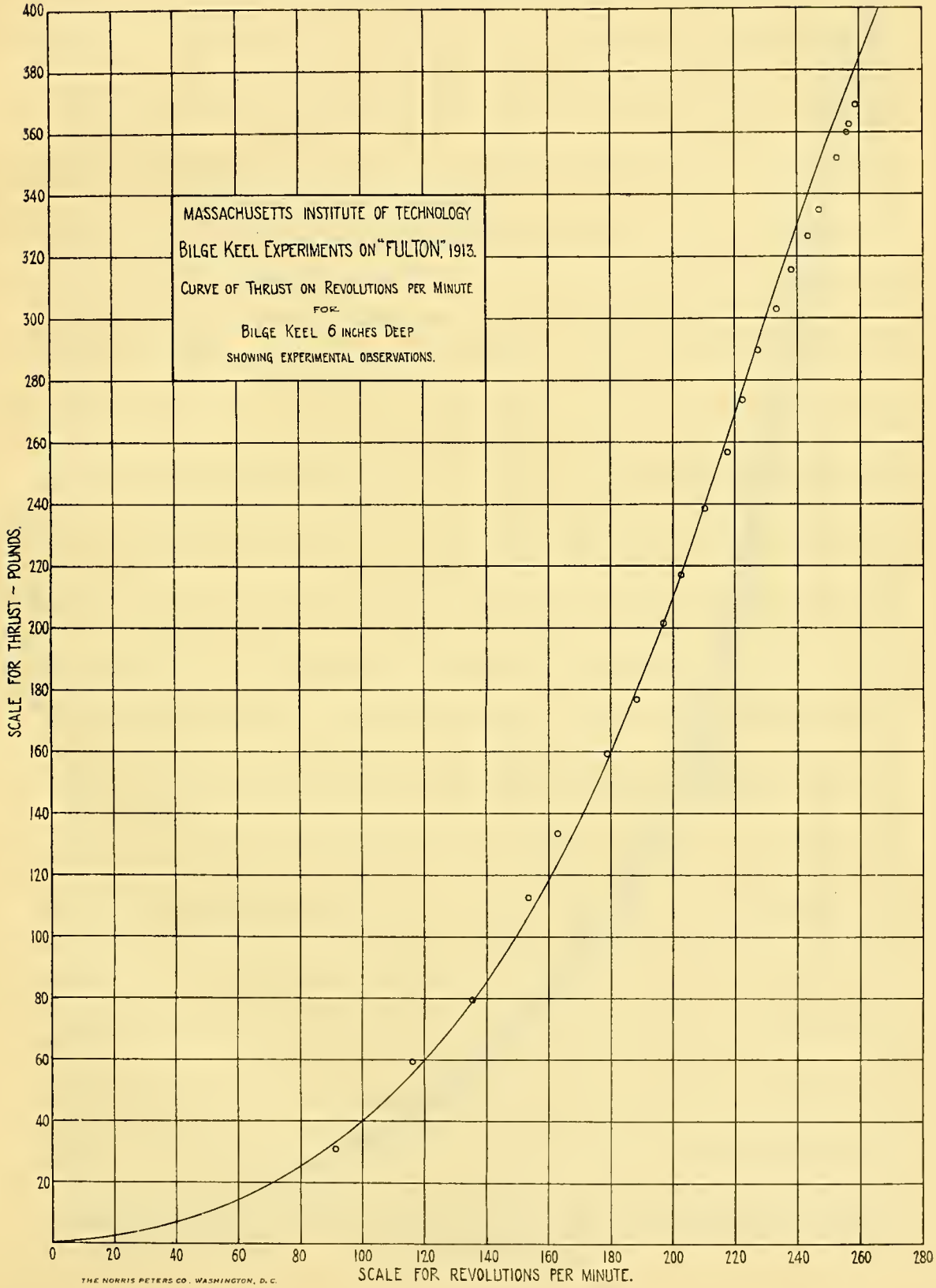

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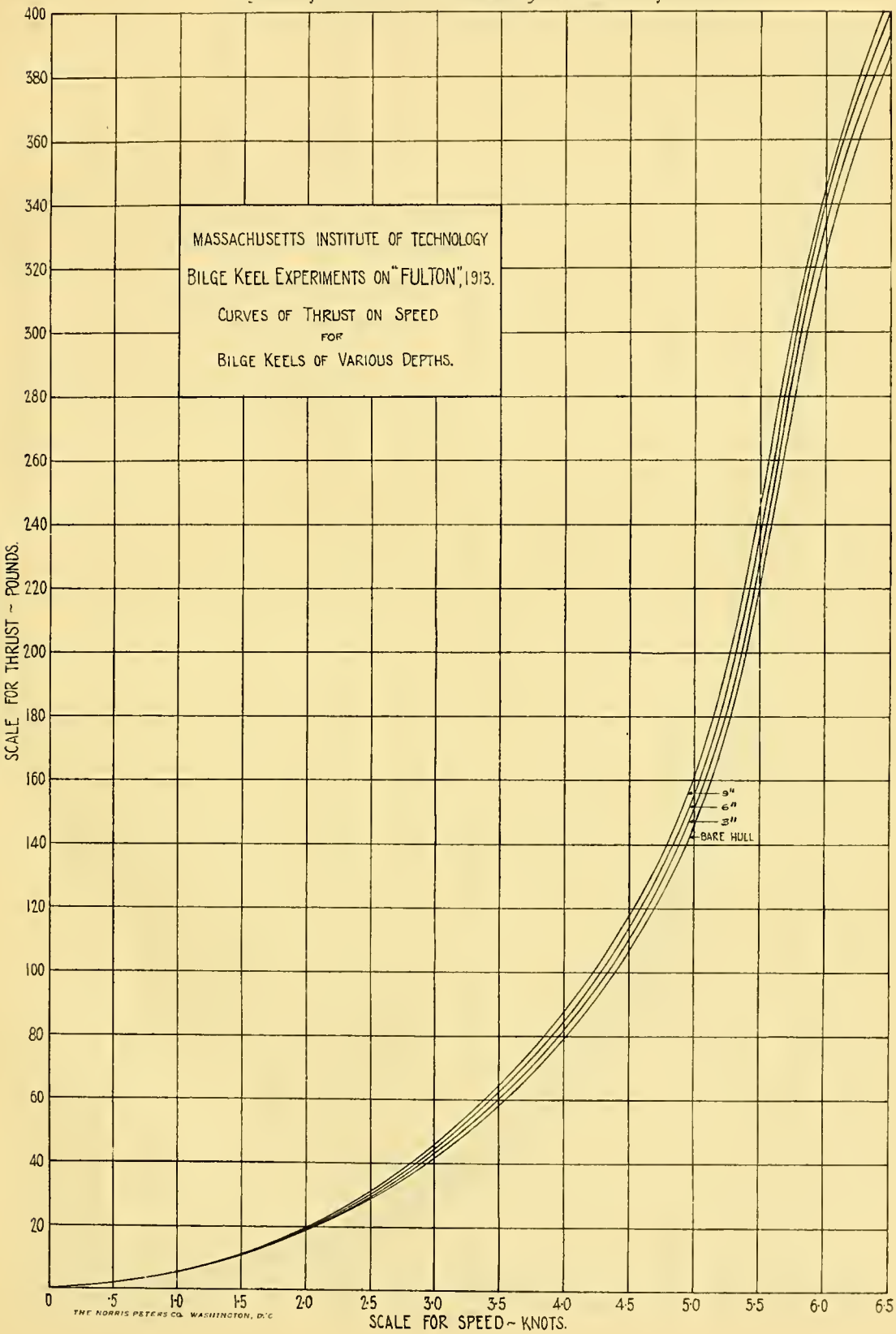

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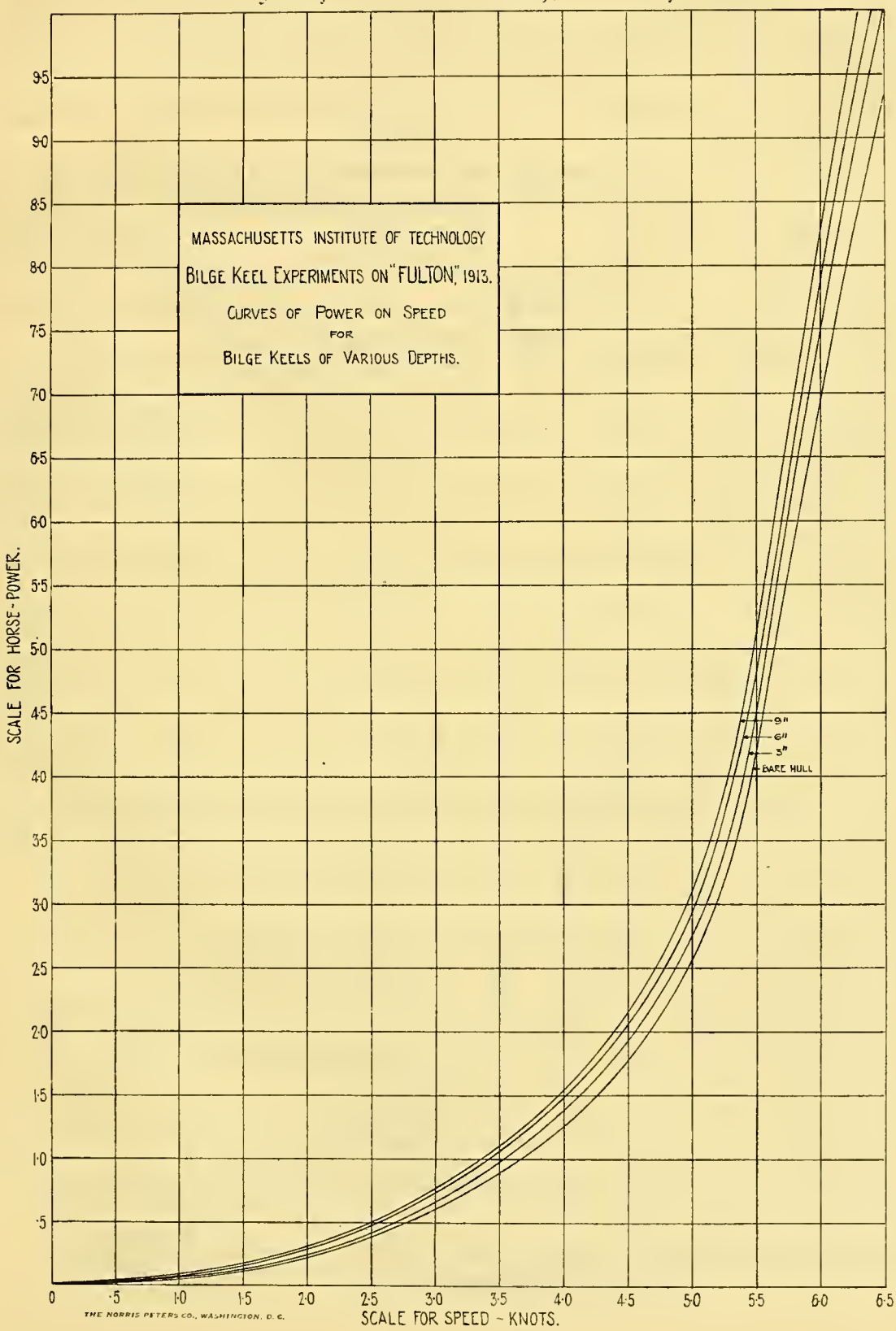

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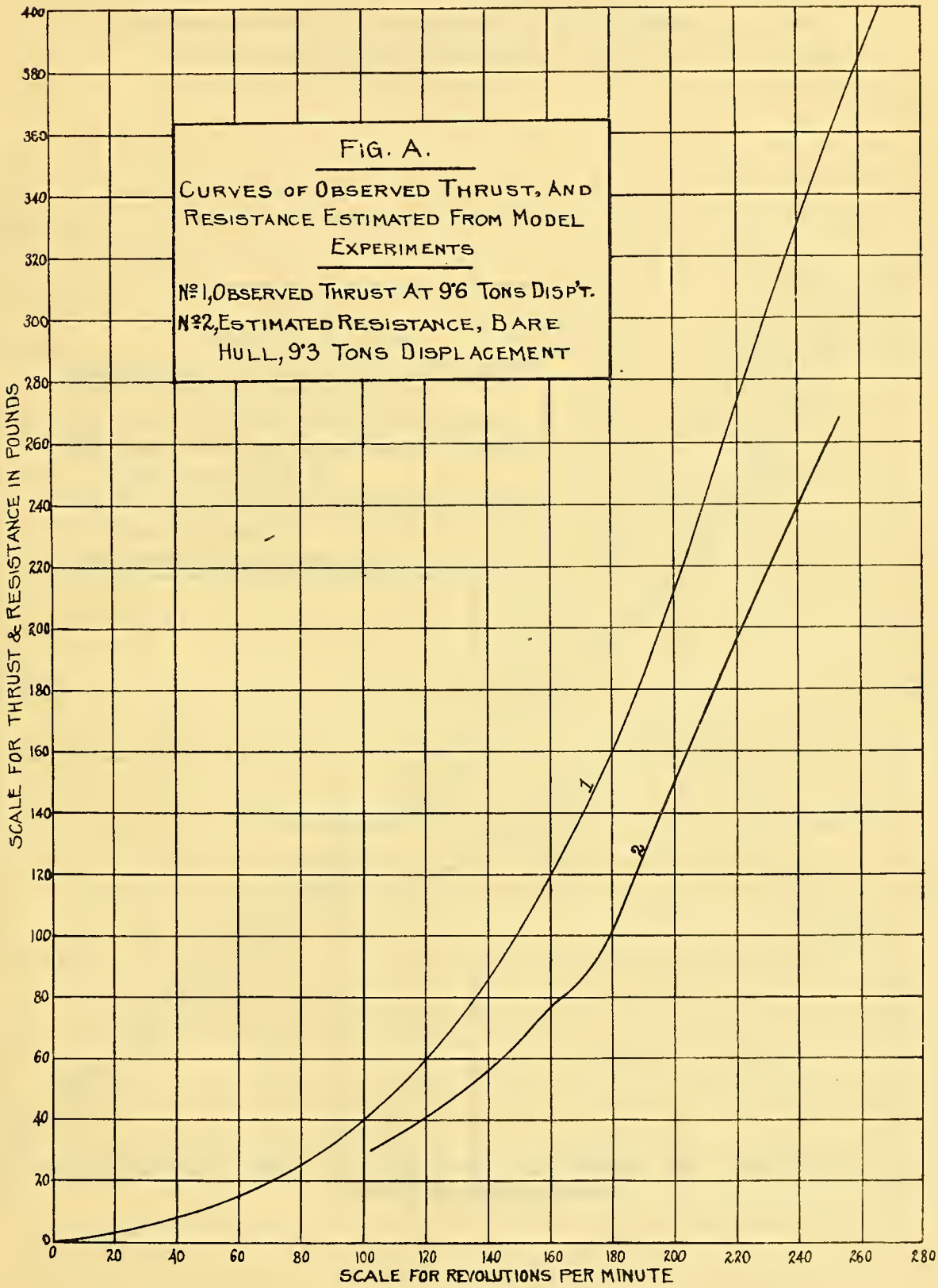

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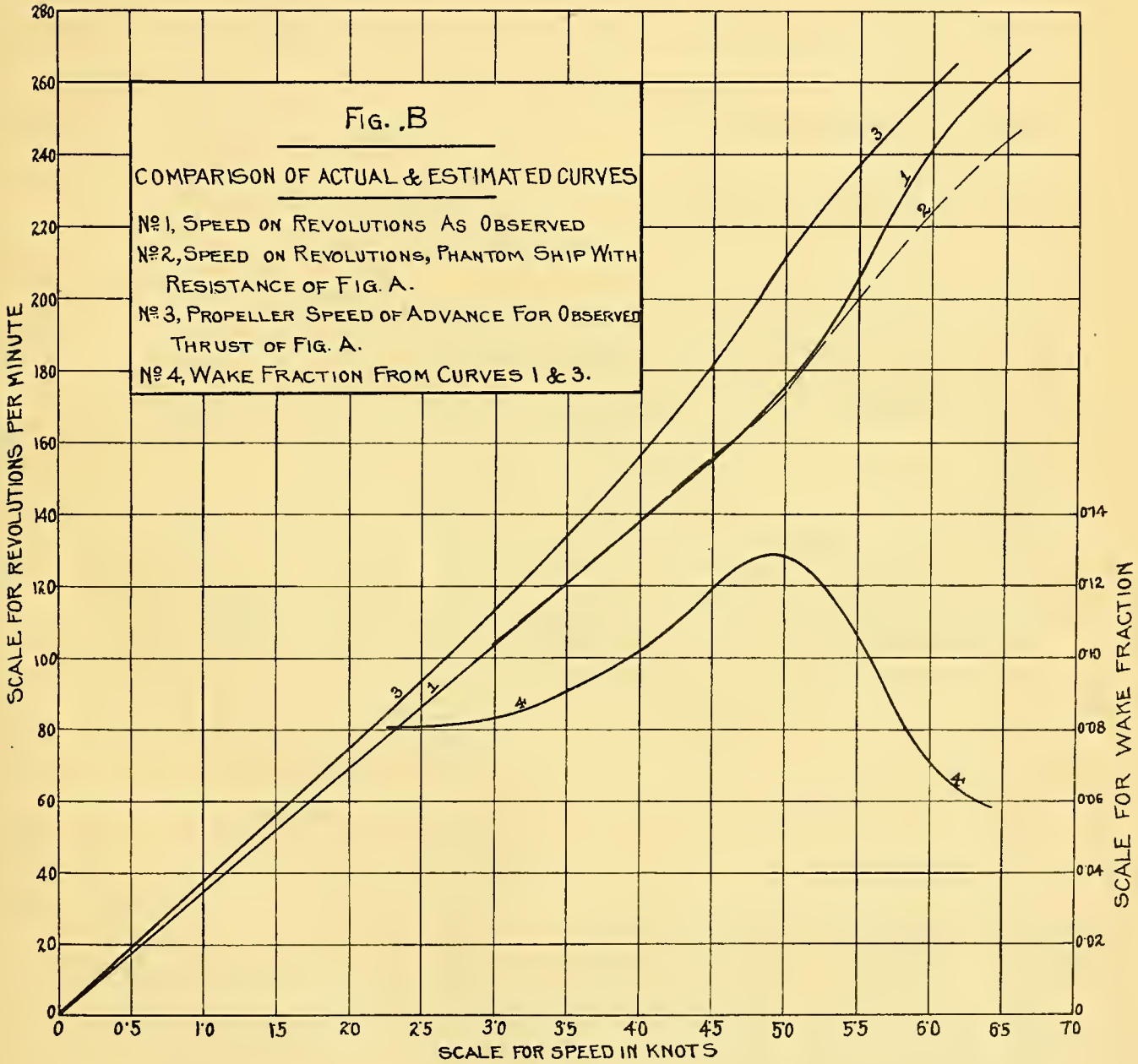
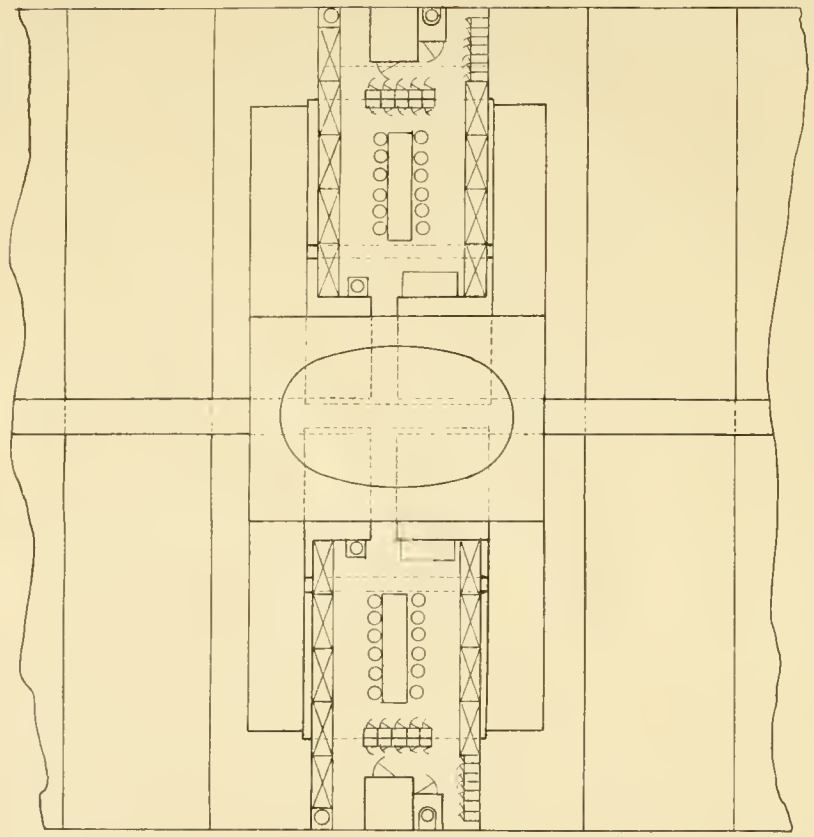
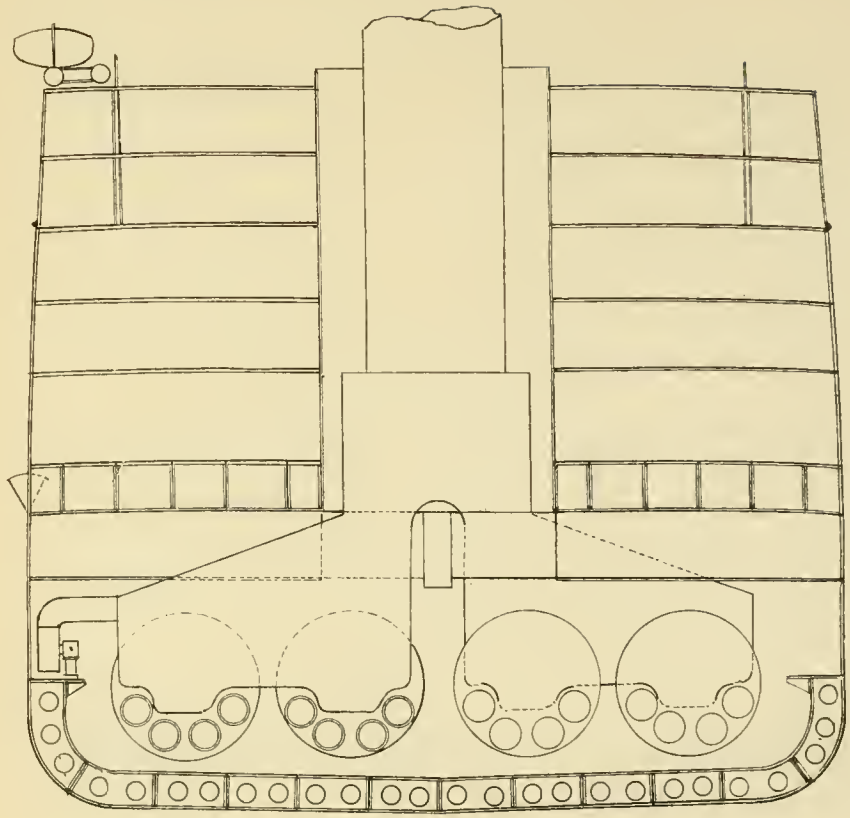
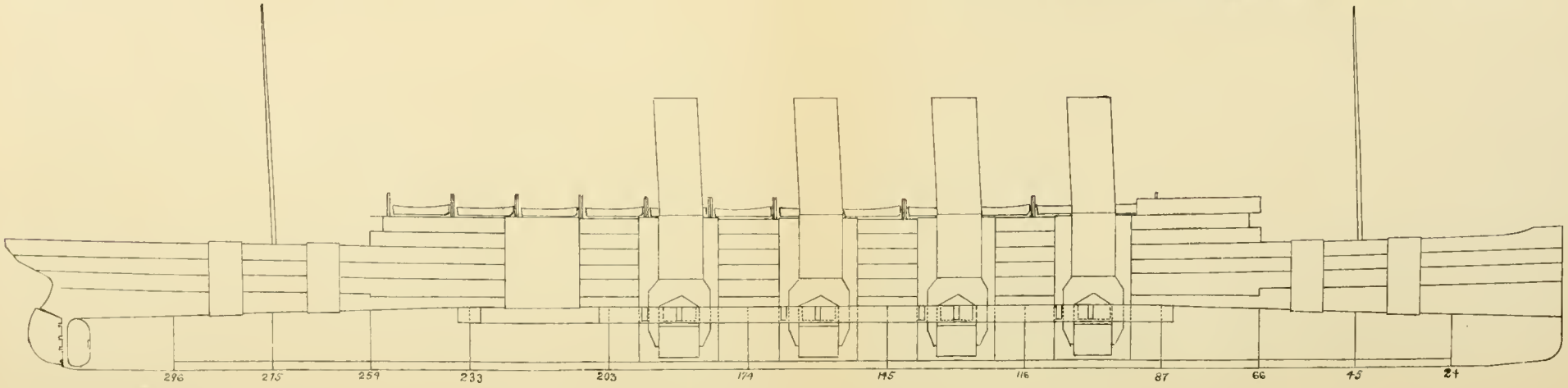


To illustrate paper on "On the Possibility of Building a Large Passenger Liner that would not under any of the Known Mishaps at Sea Lose her Buoyancy or Stability and Sink," by George W. Dickie, Esq., Vice-President.







To illustrate paper on "Structure of Vessels as Affected by Demand for Increased Safety," by William Gatewood, Esq., Member.

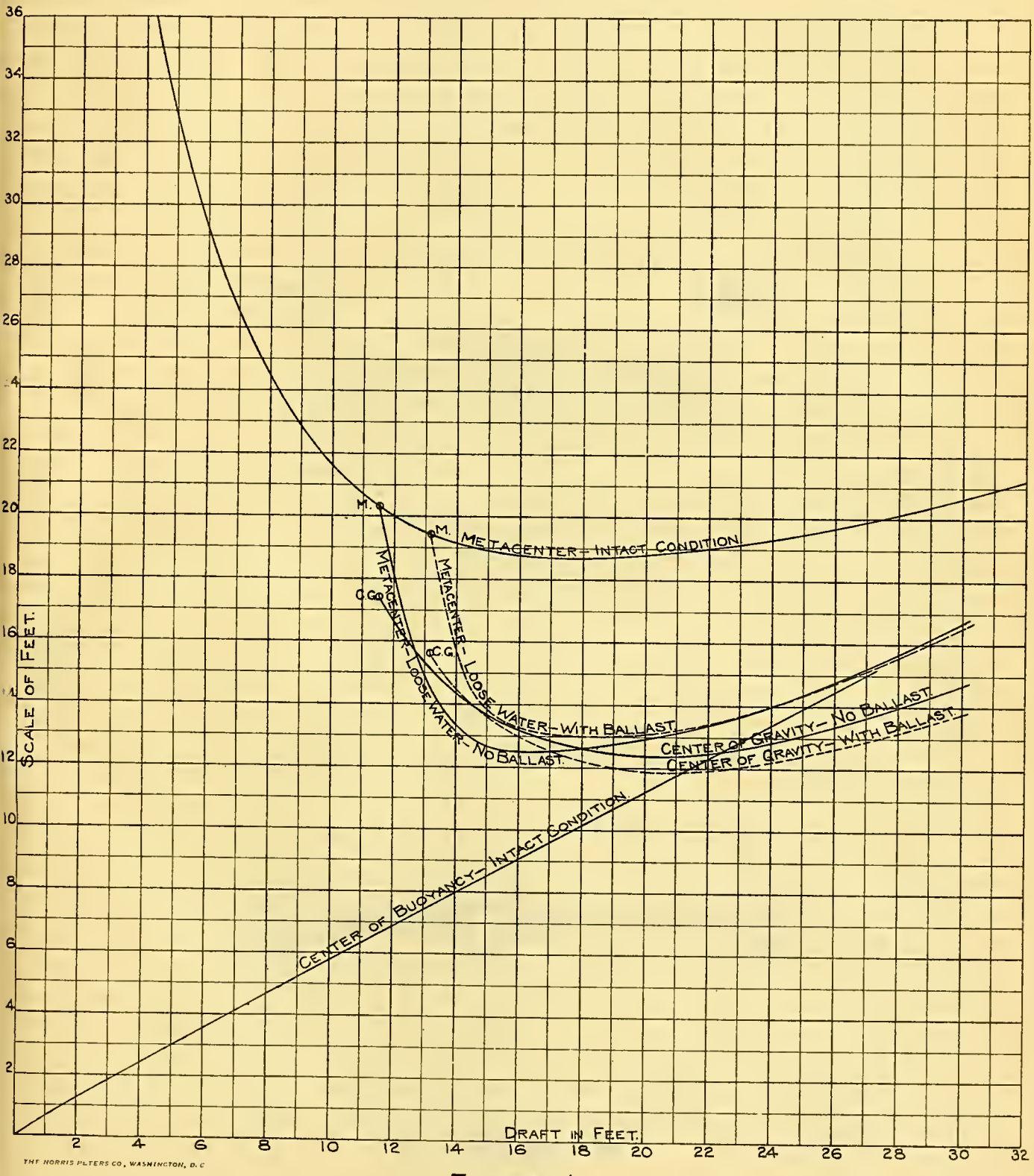


FIGURE 1.
VARIATION OF INITIAL STABILITY
IN PUMPING OUT SUNKEN PASSENGER STEAMER.

To illustrate paper on "Structure of Vessels as Affected by Demand for Increased Safety," by William Gatewood, Esq., Member.

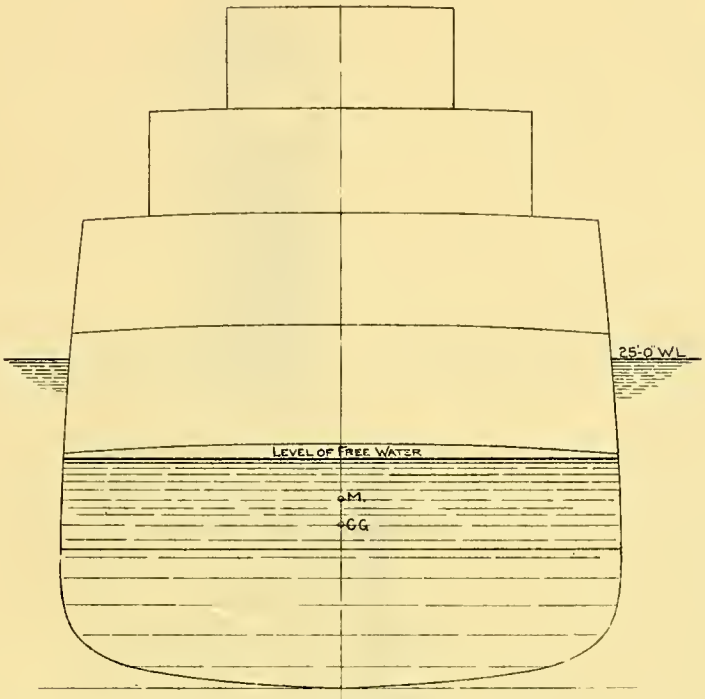


FIGURE 2.
SECTION SHOWING CONDITION AFLOAT AT 25 FT DRAFT

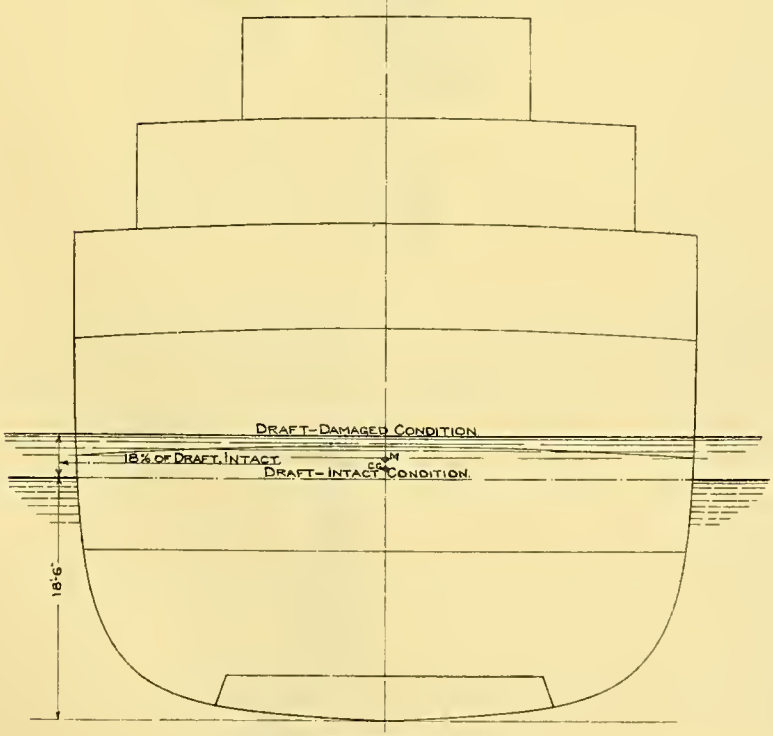


FIGURE 4.
SECTION AT AFTER BULKHEAD OF #1 HOLD.
#1 HOLD FLOODED

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To illustrate paper on "Structure of Vessels as Affected by Demand for Increased Safety," by William Gatewood, Esq., Member.

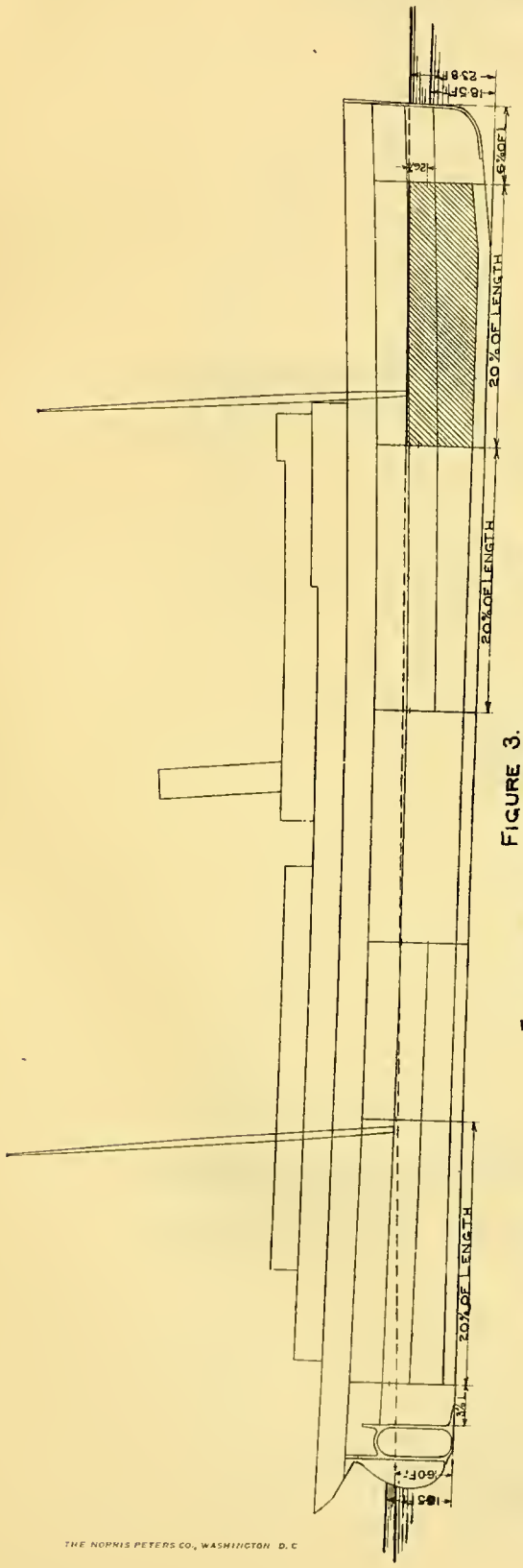

FIGURE 3.
TRIM OF COASTWISE PASSENGER STEAMER WITH #1 HOLD FLOODED
ASSUMPTIONS:— DRAFT-INTACT CONDITION-18'-6" EVEN KEEL.
CARGO - HOMOGENEOUS - DENSITY 56 CU.FT. PER TON.
VOIDS IN CARGO SPACE 50%.

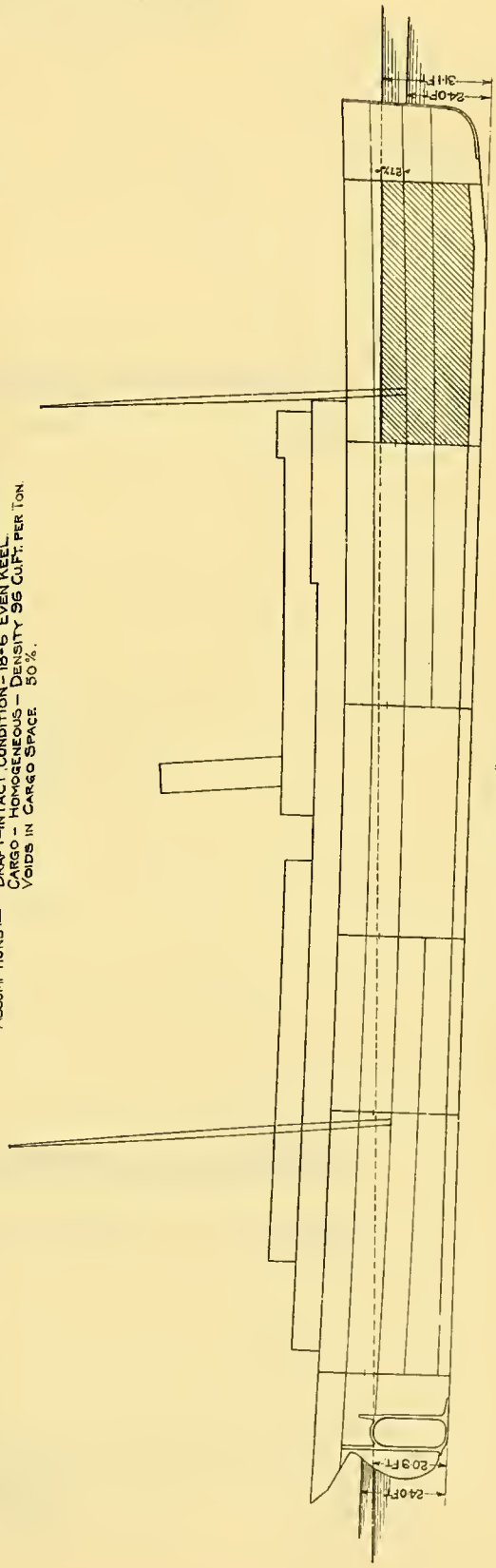

FIGURE #5
TRIM OF COASTWISE PASSENGER STEAMER WITH #1 HOLD FLOODED.
ASSUMPTIONS:— DRAFT-INTACT CONDITION-24'-0" EVEN KEEL.
CARGO- HOMOGENEOUS-DENSITY 59 CU.FT. PER TON.
VOIDS IN CARGO SPACE 50%.

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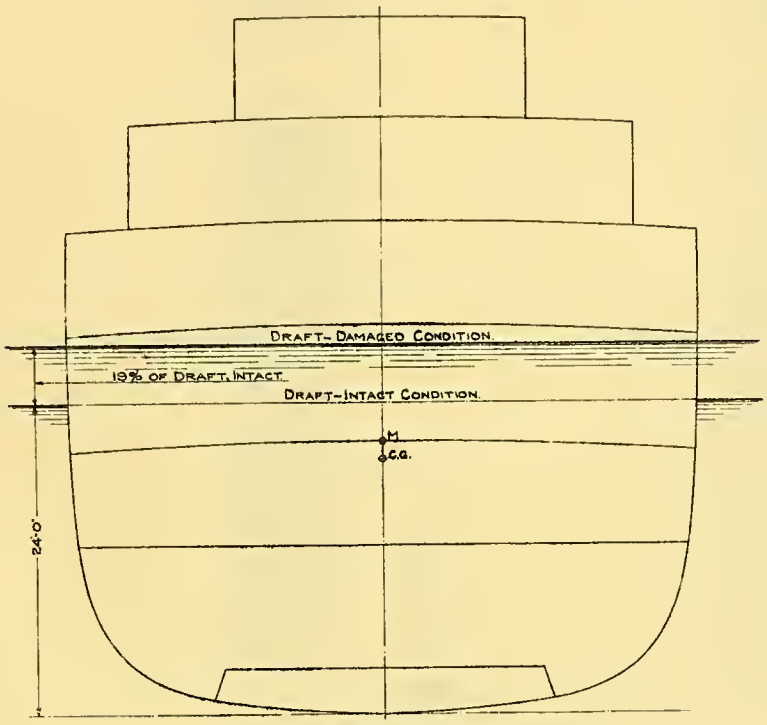

FIGURE #6
SECTION AT AFTER BULKHEAD OF #1 HOLD.
#1 HOLD FLOODED.

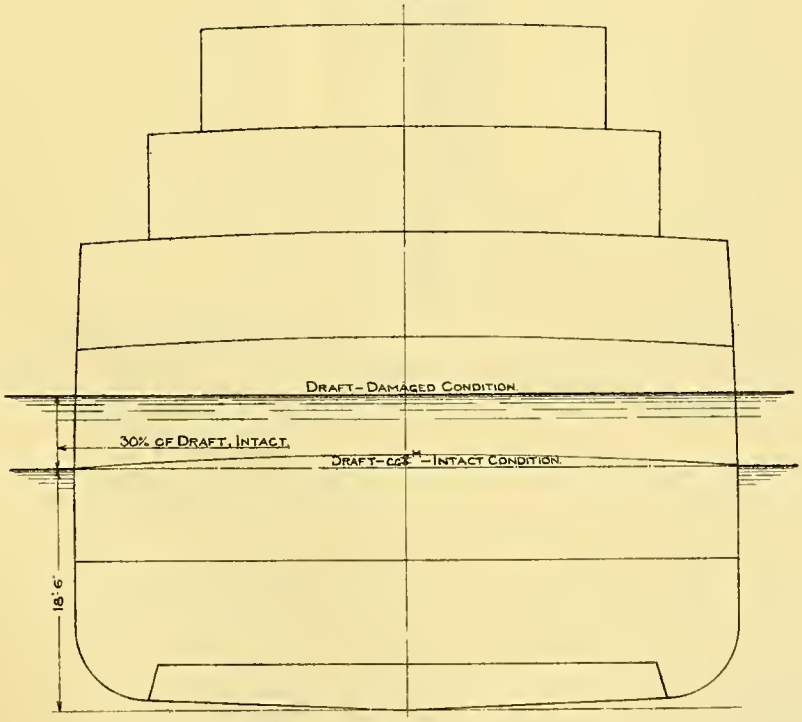

FIGURE #8.
SECTION AT AFTER BULKHEAD OF #2 HOLD
#1 & #2 HOLDS FLOODED

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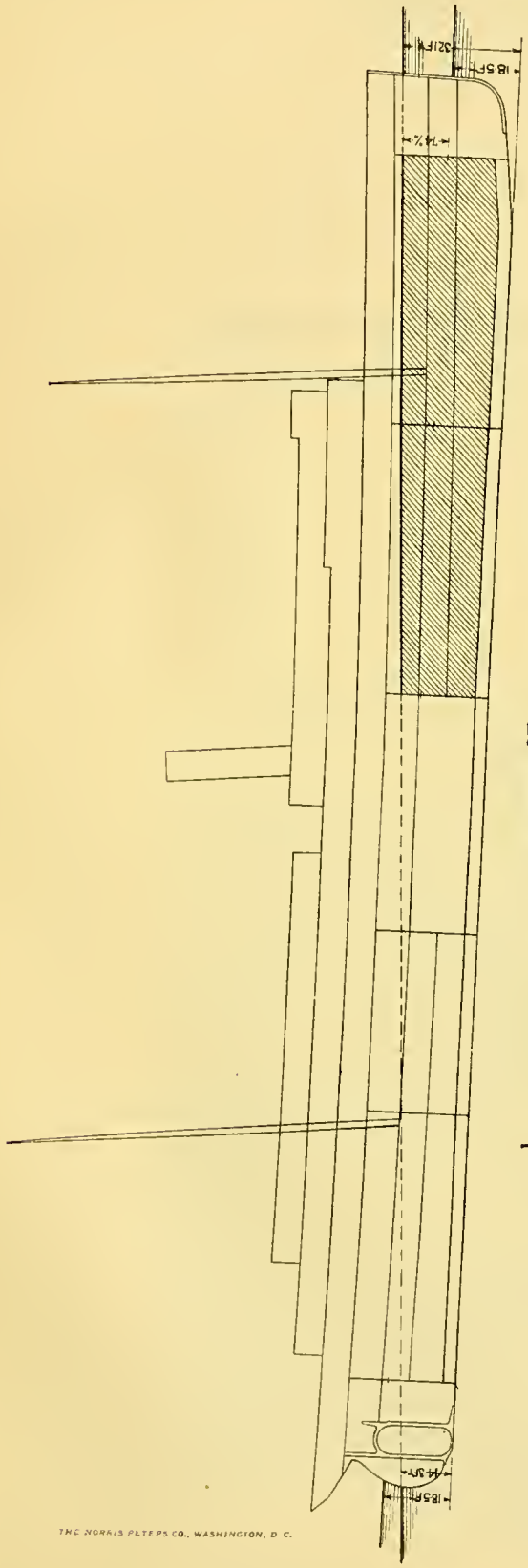

FIGURE 7.
TRIM OF COASTWISE PASSENGER STEAMER WITH 1 & 2 HOLDS FLOODED
ASSUMPTIONS:— DRAFT- INTACT CONDITION - 18'-6" EVEN KEEL
CARGO- HOMOGENEOUS - DENSITY 96 CU. FT. PER TON.
VOIDS IN CARGO SPACE 50%.

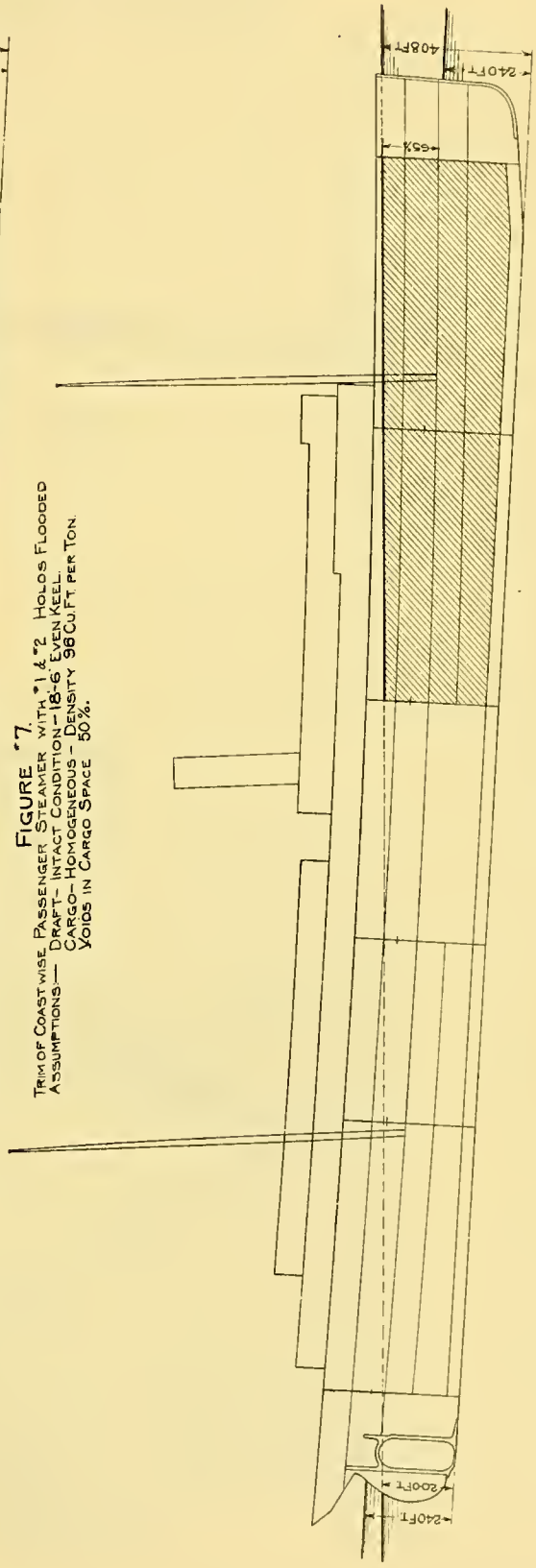

FIGURE 9.
TRIM OF COASTWISE PASSENGER STEAMER WITH 1 & 2 HOLDS FLOODED
ASSUMPTIONS:— DRAFT- INTACT CONDITION - 24'-0" EVEN KEEL.
CARGO- HOMOGENEOUS - DENSITY 59 CU. FT. PER TON.
VOIDS IN CARGO SPACE 30%

To illustrate paper on "Structure of Vessels as Affected by Demand for Increased Safety," by William Gatewood, Esq., Member.

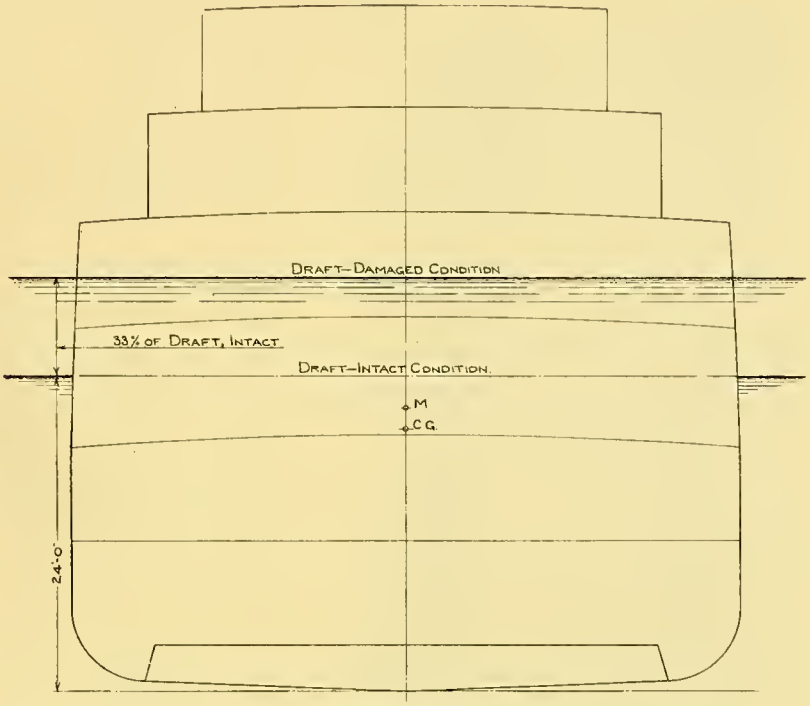

FIGURE #10
SECTION AT AFTER BULKHEAD OF #2 HOLD
#1 & #2 HOLDS FLOODED

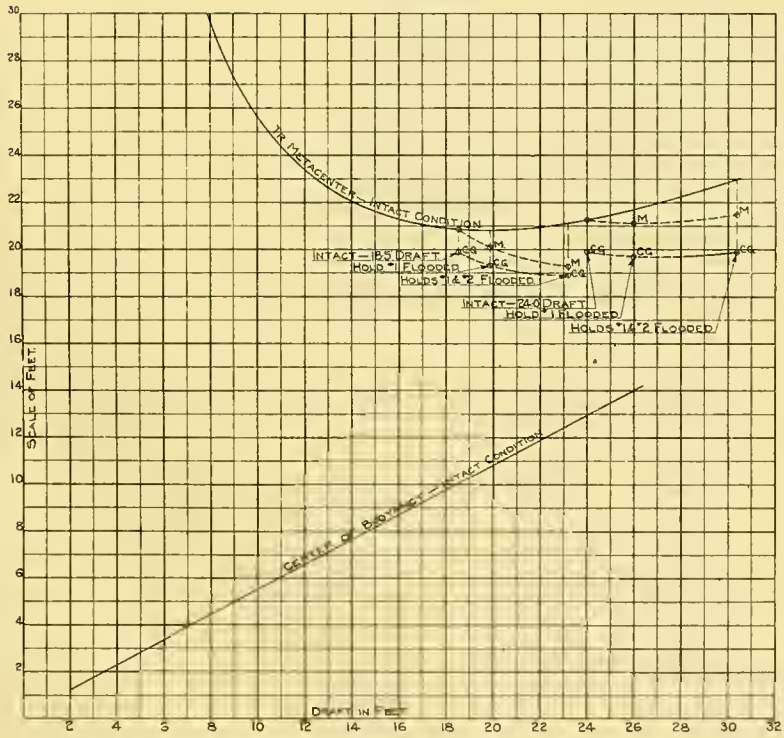

FIGURE #11
INITIAL STABILITY OF COASTWISE PASSENGER STEAMER
WITH FORWARD HOLDS FLOODED

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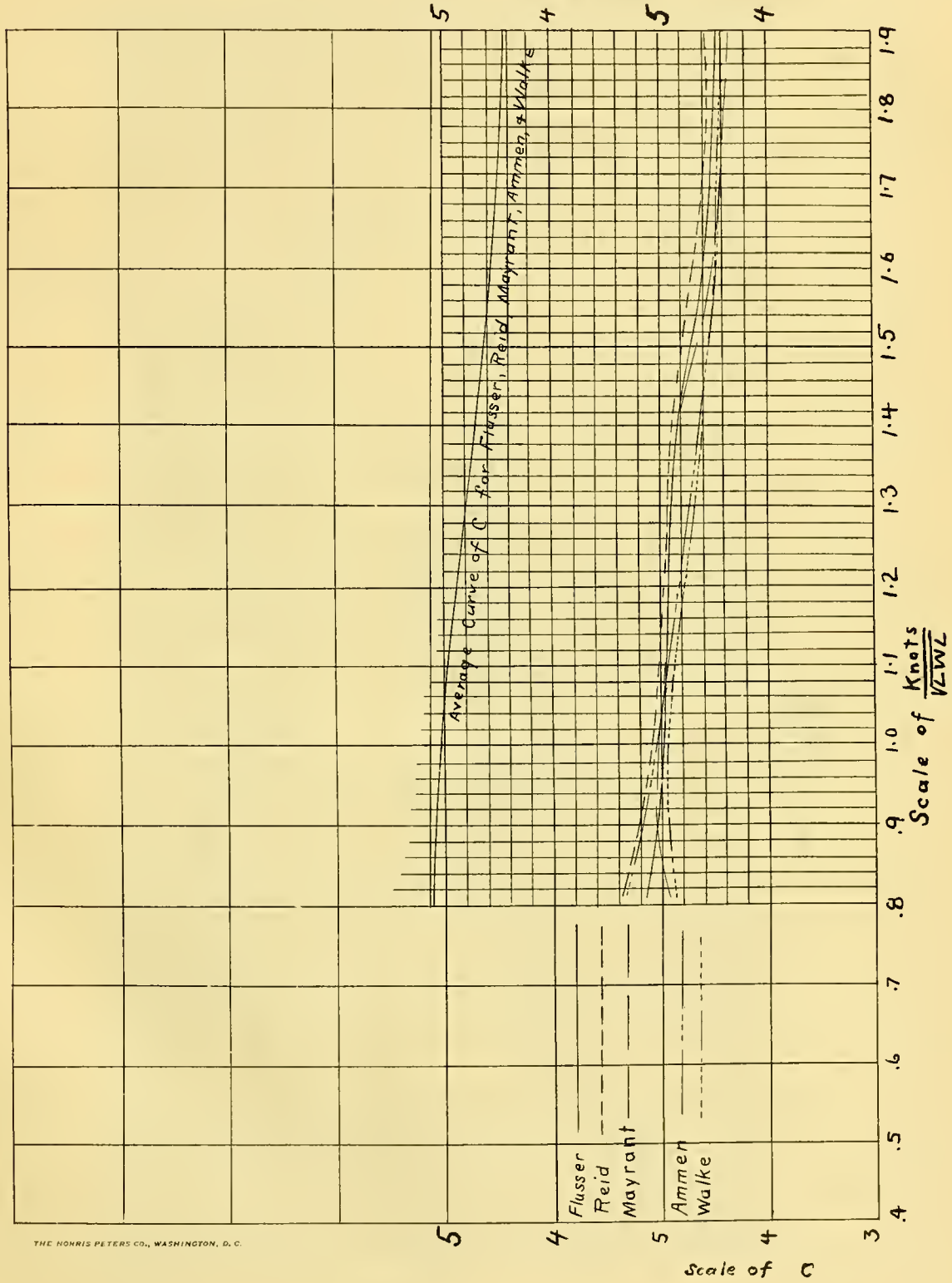
To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.



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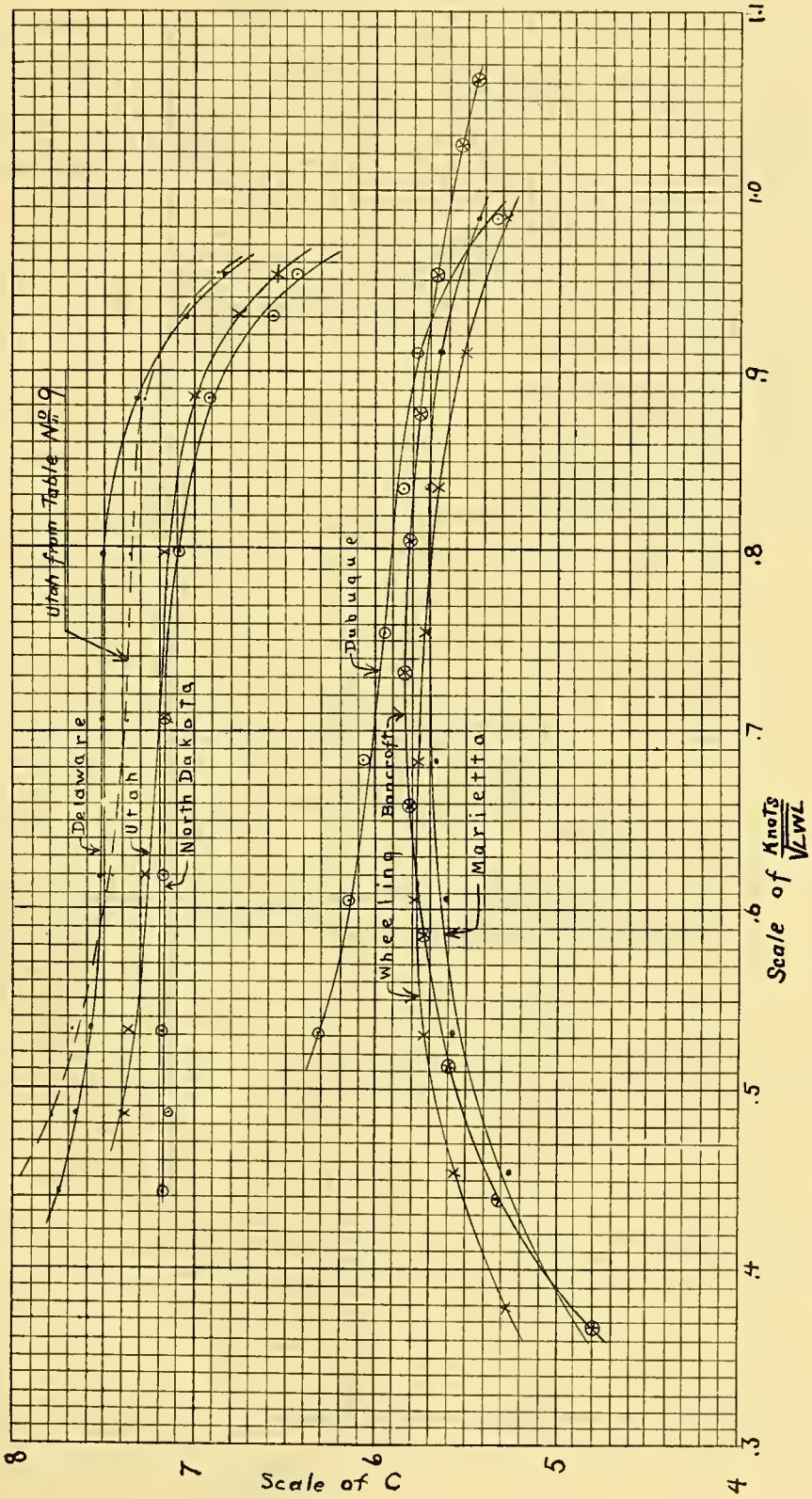

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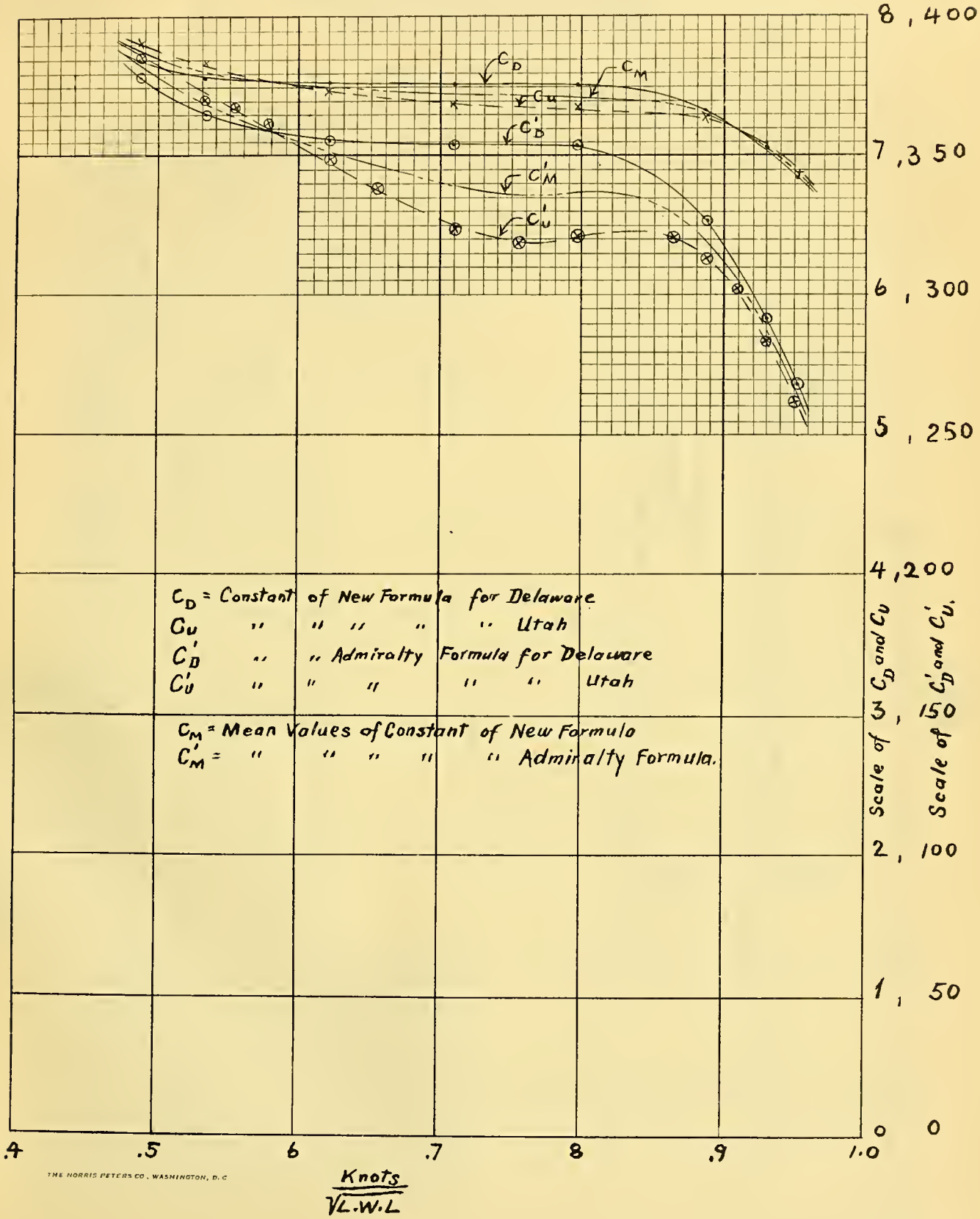

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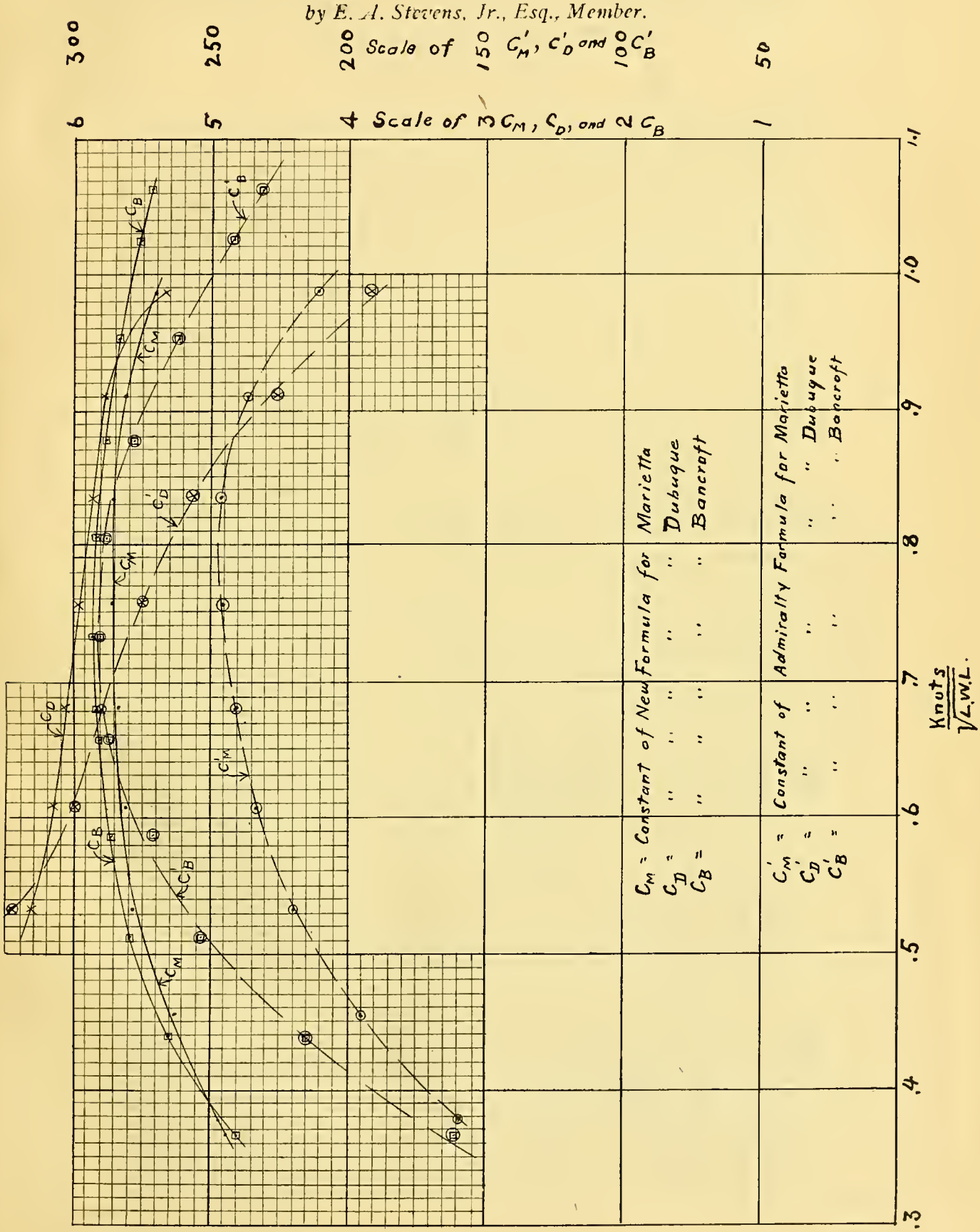

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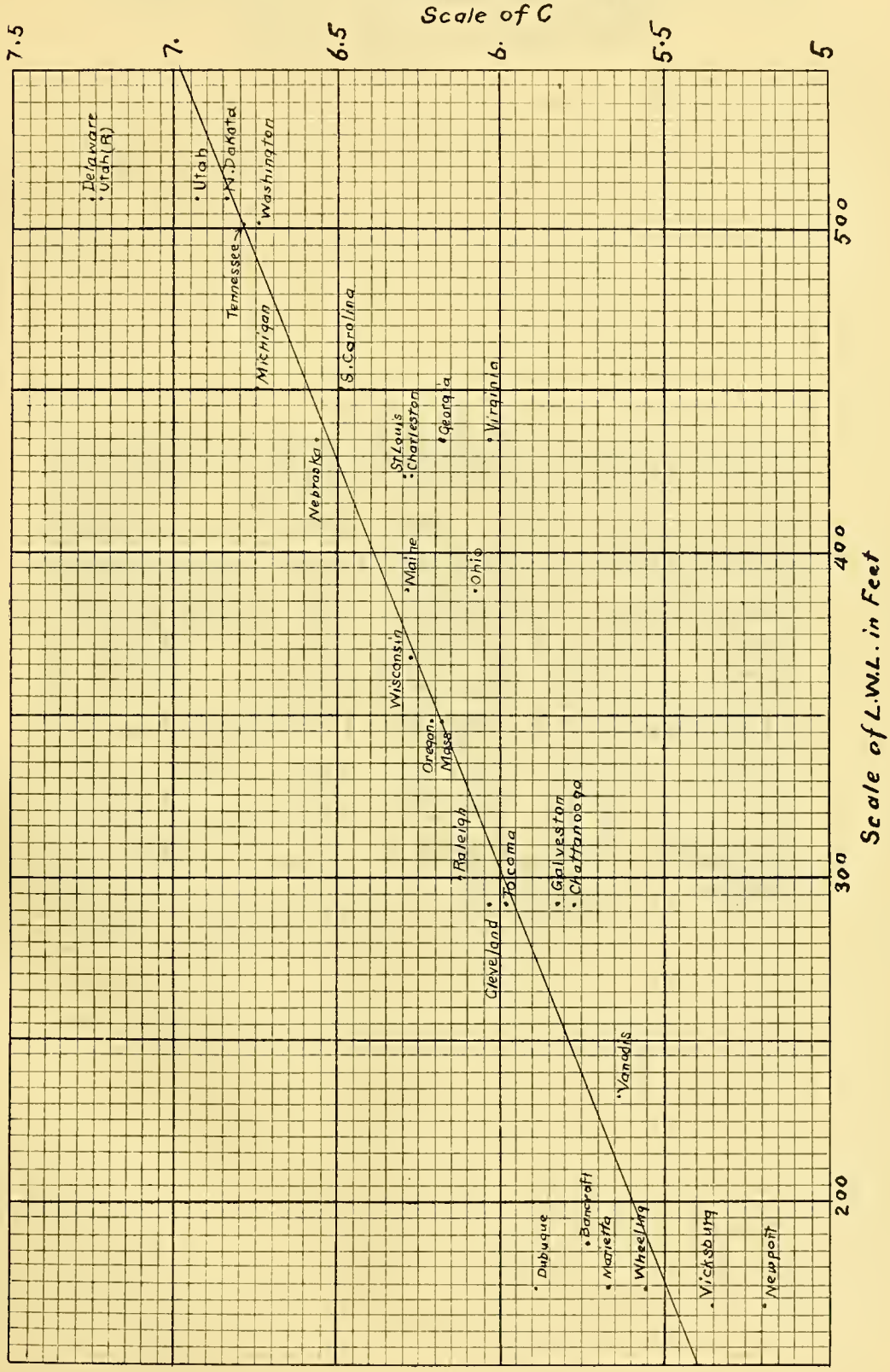

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table #1

Boat	Knots	Displacement in lbs	L.W.L	H.P.	C
Dixie	24.3	4812	40	143	42.4
Panhard II	22.?	3621	40	62.5	46.0
Vingt et Un II	22	3914	39	66.5	46.5
XPDNC	22.6	2970	42	61.	44.2
Skeeter	21.7	4638	45	85	43.6
Mercedes U.S.A	19.1	3032	32	46.5	43.2
Simplex III	15.6	2175	32	29.	36.9
Guess Again	16.2	3200	31	29.	43.8
Invlese	15.	2144	25	23.5	39.5
			Average		42.9

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To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table Nº 2

Ship	LWL feet	Displacement Tons	I.H.P.	$\frac{D}{\left(\frac{L}{100}\right)^3}$	Speed Knots	$\frac{\text{Speed}}{\sqrt{LWL}}$	C
U.S.S. Massachusetts	348	10550	11200	251.0	16.7	.897	6.174
U.S.S. Oregon	348	10250	10890	243.2	16.8	.902	6.208
U.S.S. Kearsarge	368	11738	11674	236.0	16.82	.877	6.287
U.S.S. Alabama	368	11734	11073	236.0	17.0	.887	6.474
U.S.S. Wisconsin	368	11500	12322	230.8	17.17	.895	6.270
U.S.S. Maine	388	12804	15222	220.9	18.0	.914	6.289
U.S.S. Ohio	388	12480	15950	213.7	17.82	.905	6.08
U.S.S. Missouri	388	12240	15650	209.9	18.15	.921	6.191
U.S.S. Mississippi	375	13000	12600	246.5	17.0	.878	6.405
U.S.S. Virginia	435	14978	22450	182.0	19.0	.911	6.032
U.S.S. Georgia	435	14907	20800	181.4	19.0	.911	6.173
U.S.S. Nebraska	435	14900	20700	181.0	19.0	.911	6.567
U.S.S. Kansas	450	16075	19000	176.5	18.0	.849	6.102
U.S.S. Vermont	450	15986	18500	175.5	18.5	.872	6.366
U.S.S. Michigan	450	16065	18300	176.5	19.5	.918	6.747
U.S.S. South Carolina	450	16024	19975	176.0	19.3	.910	6.488
U.S.S. Delaware	510	20099	26500	151.3	21.42	.944	6.91
U.S.S. North Dakota*	510	20020	34022	150.9	21.66	.959	6.42
U.S.S. Utah*	510	21284	29376	160.3	21.04	.931	6.688
U.S.S. Wyoming*	554	25085	34181	147.4	21.233	.914	6.687
U.S.S. Arkansas*	554	25546	31014	150.8	20.05	.853	6.63
U.S.S. West Virginia	502	13720	25726	108.5	22.15	.988	6.371
U.S.S. Maryland	502	13720	27570	108.5	22.4	1.00	6.298
U.S.S. Tennessee	502	14480	26000	114.5	22.0	.982	6.420
U.S.S. Montana	502	14518	25800	114.6	22.0	.982	6.442
H.M.S. Levianthan	500	14100	31208	112.8	23.23	1.039	6.329
H.M.S. King Alfred	500	14100	30893	112.8	23.46	1.049	6.421

*Turbines I.H.P = S.H.P. ÷ .92

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To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table # 3

Ship	L.W.L feet	Displacement in Tons	I.H.P.	$\frac{D}{(\frac{L}{100})^3}$	Speed in Knots	Speed / $\sqrt{L_{WL}}$	C.
U.S.S. Birmingham	420.00	3750	14700	50.6	24.00	1.17	5.72
U.S.S. Chester *	420.000	3977	27064	53.6	25.90	1.26	5.058
U.S.S. Salem *	420.00	4000	16576	54.0	25.00	1.22	5.688
U.S.S Columbia	411.58	7375	17452	105.8	22.80	1.128	6.284
U.SS Minneapolis	411.58	7387	20367	106.1	23.07	1.148	6.041
U.S.S. St. Louis	424.00	9665	26100	126.8	22.00	1.067	5.764
U.S.S. Charleston	424.00	9740	23000	127.7	21.30	1.030	5.836
U.S.S. Saratoga	380.54	8480	16,947	154.2	21.00	1.076	6.149
U.S.S. Brooklyn	400.50	8150	18248	126.9	21.91	1.095	6.168
U.S.S. Olympia	340.00	5586	16850	142.0	21.69	1.176	5.680
U.S.S. Baltimore	315.00	4391	9248	140.5	20.80	1.172	6.220
U.S.S. Philadelphia	327.00	4325	8533	123.6	19.67	1.088	5.968
U.S.S. Newark	310.83	3980	8512	133.0	19.00	1.078	5.667
U.S.S. San Francisco	310.00	4088	9581	137.3	19.51	1.108	5.645
U.SS Cleveland	292.00	3200	4600	12.85	16.50	.966	5.680
U.S.S. Chattanooga	292.00	3156	4950	126.7	16.50	966	5.52
U.S.S. Des Moins	292.00	3200	5059	128.5	16.65	974	5.548
U.S.S. Montgomery	257.00	2091	5484	123.2	19.05	1.189	5.47
U.S.S. Detroit	257.00	2068	5154	121.9	18.71	1.167	5.47
U.S.S. Marblehead	257.00	2073	4863	122.0	18.41	1.14	5.49
U.S.S. Nashville	220.00	1364	2488	128.2	16.29	1.098	5.413
U.S.S. Helena	250.75	1340	1953	85	15.5	.98	5.444
U.S.S Castine	204.00	1067.5	2128	125.7	16.03	1.12	5.25
U.S.S. Machias	204.00	1067.5	1795	125.7	15.46	1.08	5.36
U.S.S. Dubuque	174.00	1085	1206	206.0	13.00	.987	5.31
U.S.S. Wheeling	174.00	995	1125	188.9	13.00	.987	5.281
U.S.S. Marietta	174.00	991	1034	188.1	13.00	.987	5.423
U.SS. Bancroft	187.50	832	1184	126.2	14.37	1.049	5.34
U.S.R.C. Itasca	187.50	775	1624	117.6	15.28	1.116	4.99
U.S.S. Annapolis	168.0	943	1208	199.0	13.17	1.017	5.16
U.S.S. Vicksburg	168.0	964	1084	203.3	12.67	.978	5.15
U.S.S. Newport	168.0	972	976	205.1	12.33	.951	5.24
U.S.S. Princeton	168.0	1000	923	211.0	11.00	.849	4.81

* Turbines, I.H.P. = S.H.P. ÷ .92

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table # 4

Ship	L.W.L. in Feet	Displacement in Tons	I.H.P.	$\frac{D}{(\frac{L}{100})^3}$	Speed in Knots	$\frac{\text{Speed}}{\sqrt{L}}$	C
U.S.S. Cushing	137.50	105.3	1755	40.5	22.5	1.920	3.879
U.S.S. Ericsson	149.58	126.0	1742	37.6	21.24	1.737	3.835
U.S.S. Craven	147.00	133.0	3600	41.8	30.05	2.516	4.423
U.S.S. Rogers	160.00	147.0	2306	35.9	24.25	1.917	4.421
U.S.S. Bagley	157.00	168.0	3920	43.5	29.15	2.326	4.4
U.S.S. Biddle	157.00	168.0	3650	43.5	28.51	2.271	4.42
U.S.S. Stockton	175.00	197.0	3218	36.8	25.88	1.956	4.312
U.S.S. Thornton	175.00	174.0	3576	32.5	27.57	2.084	4.81
U.S.S. Preble	245.00	480.0	7500	32.6	28.50	1.82	4.557
U.S.S. Barry	240.50	462.0	7950	30.3	28.13	1.812	4.367
U.S.S. Truxton	258.50	479.3	7846	27.7	29.58	1.839	4.616
U.S.S. Hopkins	244.00	479.0	8400	33.0	28.00	1.792	4.311
U.S.S. Flusser *	289.00	686.0	12545	28.4	30.41	1.789	4.489
U.S.S. Reid *	289.00	690.0	13502	28.5	31.82	1.870	4.586
U.S.S. Lamson *	289.00	690.0	11520	28.5	28.605	1.680	4.353
U.S.S. Paulding *	289.00	711.0	18481	29.4	32.80	1.930	4.306
U.S.S. Roe *	289.00	711.0	13001	29.4	29.60	1.740	4.369
U.S.S. Ammem *	289.00	735.9	15218	30.4	30.48	1.794	4.320
U.S.S. Monaghan *	289.00	734.8	13490	30.4	30.45	1.790	4.489
U.S.S. Mayrant *	289.00	734.0	14282	30.4	30.22	1.780	4.369
U.S.S. Trippe *	289.00	733.0	16236	30.3	30.89	1.817	4.277
U.S.S. Warrington *	289.00	742.0	15870	30.7	31.40	1.844	4.399
U.S.S. Beale *	289.00	740.0	12826	30.6	29.65	1.744	4.366
U.S.S. Patterson *	289.00	756.8	13720	31.4	29.685	1.748	4.394
U.S.S. Sterrett *	289.00	754.0	13901	31.2	30.37	1.783	4.471
U.S.S. Perkins *	289.00	761.0	15033	31.5	31.2	1.835	4.489
U.S.S. Walke *	289.00	772.0	13667	32.0	29.78	1.750	4.444

*Turbines, I.H.P. = S.H.P. ÷ .92

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table # 5

Ship	LWL in Feet	Displacement in Tons	I.H.P.	$\frac{D}{\left(\frac{L}{100}\right)^3}$	Speed in Knots	$\frac{\text{Speed}}{\sqrt{LWL}}$	C.
U.S.S. Ozark	252.00	3275	2190	204.7	12.71	.801	5.84
U.S.S. Tallahasse	252.00	3275	2317	204.7	12.40	.781	5.54
U.S.S. Tonopah	252.00	3275	1940	204.7	13.04	.822	6.18
U.S.S. Cheyenne	252.00	3275	2550	204.7	12.50	.788	5.41
U.S.S. Mars	387.00	11282	4150	195	13.20	.663	7.328
U.S.S. Cyclops	528.00	19270	8400	131	15.50	.674	7.184
U.S.S. Orion	514.00	18800	6943	138.3	14.47	.638	7.124
S.S. Creole (Rec.)	440	9700?	7196	113.9	16.1	.767	6.65
S.S. Creole (Turbine)	440	9700	6388	113.9	15.0	.715	6.25
S.Y. Vanadis	232.67	1467	1400	117.4	13.75	.902	5.64
50 ft. U.S.N. Launch	50	19.77	412	158.2	11	1.56	2.09
36 ft. U.S.N. Launch	34.?	7.14	19	181.7	7.5	1.28	3.01
33 ft. U.S.N. Launch	31.?	6.2	19	207.4	7.5	1.35	2.92
28 ft U.S.N. Launch	26.5	4.42	14.5	238.5	6.69	1.3	2.61
56 ft. U.S.N. Launch	56	13.75	315	78.5	19.25	2.57	3.47

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To illustrate paper on "A Substitute for the Admiralty Formula,"
by E. A. Steens, Jr., Esq., Member.

Table # 6

Knots	Knots / √LWL	Flusser 686 Tons		Reid 690 Tons		Mayrant 734 Tons		Ammen 735.9 Tons		Walke 772 Tons		Average
		I.H.P.	C	I.H.P.	C	I.H.P.	C	I.H.P.	C	I.H.P.	C	C
34	2.00			16300	4.57							
33	1.941	16100	4.48	15170	4.63							
32	1.882	14790	4.47	13910	4.58	17050	4.36	17000	4.37			4.44
31	1.823	13310	4.49	13200	4.51	15280	4.38	15600	4.36	15850	4.41	4.45
30	1.765	11960	4.50	11470	4.58	13580	4.42	14010	4.37	14120	4.43	4.46
29	1.705	10650	4.52	10180	4.60	12070	4.44	12280	4.42	12500	4.46	4.49
28	1.647	9400	4.56	8910	4.64	10700	4.46	10750	4.46	11030	4.49	4.52
26	1.529	7125	4.65	6750	4.73	8050	4.55	8370	4.50	8530	4.45	4.58
24	1.412	5110	4.78	4880	4.88	5540	4.77	6080	4.62	6360	4.62	4.74
22	1.294	3696	4.89	3690	4.90	3910	4.89	4290	4.75	4620	4.61	4.81
20	1.177	2687	4.95	2610	5.00	2825	4.96	2930	4.91	3260	4.82	4.93
17	1.000	1610	4.98	1500	5.11	1685	5.02	1685	5.04	1848	4.95	5.02
14	.824	816	5.15	728	5.35	978	4.96	903	5.31	1087	4.87	5.11

THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table # 7

Knots	Knots / √L.W.L.	Delaware 20099 Tons		North Dakota 20020 Tons		Utah 21268 Tons	
		I.H.P.	C	I.H.P.	C	I.H.P	C
21½	.952	27300	6.86	32900	6.44	33540	6.55
21	.930	23400	7.05	27950	6.58	28400	6.76
20	.886	18050	7.32	21500	6.92	21950	7.00
18	.797	12200	7.51	13750	7.09	14900	7.18
16	.708	8550	7.52	10100	7.17	10540	7.18
14	.620	5700	7.53	6640	7.18	6850	7.26
12	.531	3500	7.59	4130	7.19	4130	7.37
11	.487	2600	7.68	3260	7.14	3150	7.39
10	.443	1900	7.75	2500	7.19		
9							

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To illustrate paper on "A Substitute for the Admiralty Formula,"
by E. A. Stevens, Jr., Esq., Member.

Table #8

Knots	Marietta; LWL. 174'; 991 Tons			Wheeling; LWL. 174'; 995 Tons			Dubuque; LWL 174'; 1085.3			Bancroft; LWL 187'-6"; 832 Tons		
	Knots / √L.W.L.	I.H.P.	C	Knots / √L.W.L.	I.H.P.	C	Knots / √L.W.L.	I.H.P.	C	Knots / √L.W.L.	I.H.P.	C
14.52										1.063	1170	5.45
14										1.025	1008	5.52
13	.987	1034	5.42	.987	1125	5.28	.987	1206	5.31	.952	745	5.68
12	.910	730	5.65	.910	783	5.50	.910	812	5.79	.878	550	5.77
11	.835	538	5.71	.835	555	5.66	.835	548	5.85	.805	410	5.82
10	.757	404	5.71	.757	400	5.73	.757	384	5.95	.732	305	5.85
9	.683	300	5.68	.683	284	5.78	.683	264	6.08	.659	225	5.81
8	.607	217	5.62	.607	200	5.79	.607	180	6.15	.586	168	5.71
7	.531	155	5.59	.531	138	5.72	.531	112	6.31	.512	120	5.60
6	.455	110	5.28	.455	95	5.56	.455			.439	89	5.31
5	.379	78	4.94	.379	65	5.27	.379			.366	69	4.80

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To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table # 9

Knots	Knots / √LWL	Delaware				Utah			
		Propulsive Coefficent	I.H.P.	C_D	C_D'	E.H.P.	I.H.P.	C_u	C_u'
21½	.952	54.8	27300	6.86	269	15900	29000	6.87	263
21	.930	55.4	27400	7.05	292	13900	25100	7.09	283
20	.886	55.5	18050	7.32	327	10900	19650	7.28	313
18	.797	54.8	12200	7.51	353	7650	13950	7.35	321
16	.708	53.5	8500	7.52	354	5200	9720	7.37	324
14	620	54.7	5700	7.53	356	3300	6030	7.48	349
12	531	58.0	3500	7.59	365	2070	3570	7.69	371
11	487	60.3	2600	7.68	379	1600	2650	7.80	386

C_D = Constant of New Formula for Delaware

C_u = " " " " " Utah

C_D' = " " Admiralty Formula for Delaware

C_u' = " " " " " Utah

Note; I.H.P. for Utah = E.H.P. for Utah ÷ Propulsive Coefficent of Delaware

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To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table #10

Knots	Marietta, LWL = 174'; 991 Tons				Dubuque, LWL = 174'; 1085.3 Tons				Bancroft, LWL = 187'-6"; 832 Tons			
	$\frac{\text{Knots}}{\sqrt{LWL}}$	I.H.P.	C_M	C'_M	$\frac{\text{Knots}}{\sqrt{LWL}}$	I.H.P	C_D	C'_D	$\frac{\text{Knots}}{\sqrt{LWL}}$	I.H.P	C_B	C'_B
14.52									1.063	1170	5.45	232
14									1.025	1008	5.52	242
13	.987	1034	5.42	211	.987	1206	5.31	192	.952	745	5.68	262
12	.910	730	5.65	236	.910	812	5.79	225	.878	550	5.77	279
11	.835	538	5.71	246	.835	548	5.85	257	.805	410	5.82	289
10	.757	404	5.71	246	.757	384	5.95	275	.732	305	5.85	291
9	.683	300	5.68	241	.683	264	6.08	291	.659	225	5.81	288
8	.607	217	5.62	234	.607	180	6.15	300	.586	168	5.71	271
7	.531	155	5.59	220	.531	112	6.31	323	.512	120	5.60	254
6	.455	110	5.28	195	.455				.439	89	5.31	216
5	.379	78	4.94	159	.375				.366	69	4.80	161

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C_M = Constant of New Formula for Marietta
C_D = " " " " " Dubuque
C_B = " " " " " Bancroft
C'_M = " " Admiralty " " Marietta
C'_D = " " " " " Dubuque
C'_B = " " " " " Bancroft

To illustrate paper on "A Substitute for the Admiralty Formula,"
by E. A. Stevens, Jr., Esq., Member.

Table No 11

Ship	L.W.L. Feet	D Tons	IHP	Knots	$\frac{\text{Knots}}{\sqrt{\text{L.W.L}}}$	$\frac{D}{\left(\frac{\text{LWL}}{100}\right)^3}$	C
Newport	168	972	855	11.66	.9	205.1	5.19
Vicksburg	168	964	775	11.66	.9	203.3	5.35
Dubuque	174	1085		11.87	.9	206	5.79†
Marietta	174	991		11.87	.9	188.1	5.66†
Wheeling	174	995		11.87	.9	188.9	5.55†
Bancroft	187.5	832		12.29	.9	124.8	5.73†
Vanadis	232.67	1467	1400	13.75	.902	117.4	5.64
Cleveland	292	3200	3100	15.37	.9	128.5	6.04
Tacoma	292	3250	3250	15.37	.9	130.5	5.98
Galveston	292	3250	3530	15.37	.9	130.5	5.82
Chattanooga	292	3200	3575	15.37	.9	128.5	5.77
Raleigh	300	3183	2900	15.59	.9	117.9	6.22
Massachusetts	348	10550	11200	16.7	.897	251	6.174
Oregon	348	10250	10890	16.8	.902	243.2	6.208
Wisconsin	368	11500	12322	17.17	.895	230.8	6.270
Maine	388	12804	15222	18.0	.914	220.9	6.289
Ohio	388	12480	15950	17.82	.905	213.7	6.08
St Louis	424	9665	12100	18.53	.9	126.8	6.29
Charleston	424	9710	12200	18.53	.9	127.7	6.27
Nebraska	435	14900	20700	19.00	.911	181.0	6.567
Georgia	435	14907	20800	19.00	.911	181.4	6.173
Virginia	435	14978	22450	19.00	.911	182.0	6.032
Michigan	450	16065	18300	19.50	.918	176.5	6.747
South Carolina	450	16024	19975	19.30	.910	176.0	6.488
Washington	502	14495	17350	20.17	.9	115.3	6.74
Tennessee	502	14480	17000	20.17	.9	114.5	6.79
Delaware	510	20099		20.32	.9	151.3	7.26†
Utah (Recip)	510	21268		20.32	.9	160.3	7.24†
Utah (Turbine)	510	21268		20.32	.9	160.3	6.94†
North Dakota.	510	20020		20.32	.9	150.9	6.84†

†. Values of C are taken from curves on Plate No 2

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To illustrate paper on "A Substitute for the Admiralty Formula," by E. A. Stevens, Jr., Esq., Member.

Table Nº 12

Viqnt et Un II LWL 38'-9"; Displacement 1.72 Tons			Elco Express L.W.L. 31'-0"; Displacement 1.19 Tons		
Knots	I.H.P.*	C	Knots	I.H.P.†	C
22	84	3.28	22	57.4	3.41
20	66	3.23	20	45.6	3.35
18	51.7	3.15	18	36.	3.26
16	39.2	3.07	16	27	3.2
14	28.4	2.99	14	20	3.08
12	18.7	2.95	12	13.6	3.0
10	11.9	2.88	10	8.6	2.93

*I.H.P = B.H.P. ÷ .88

† I.H.P = E.H.P. ÷ .5

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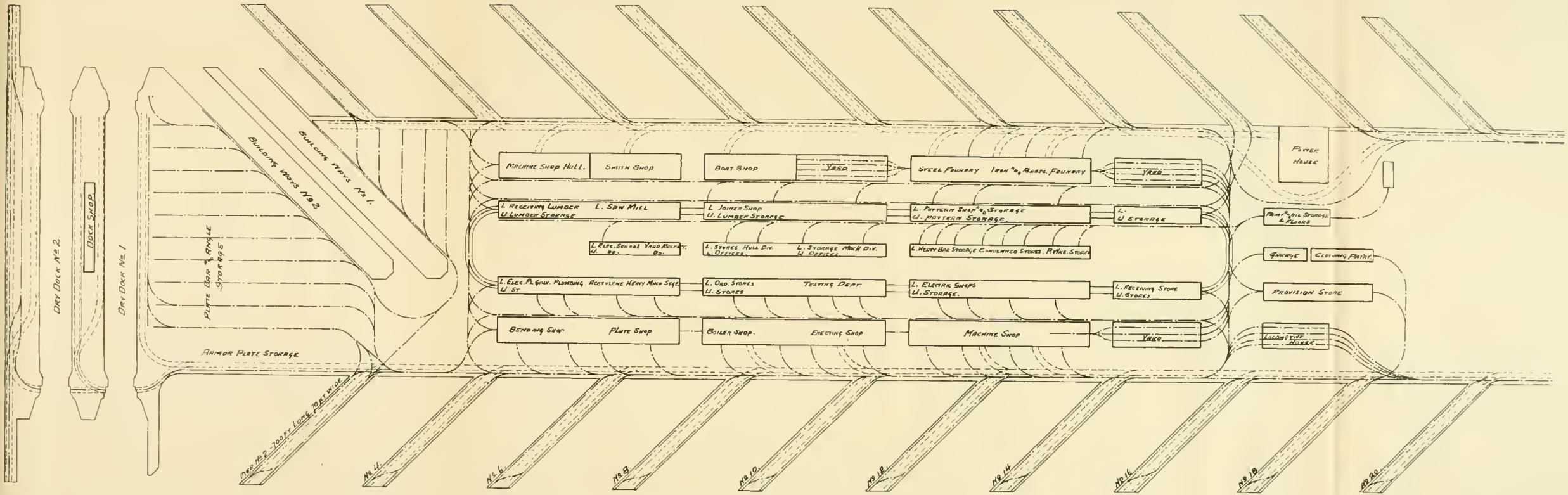
To illustrate paper on "General Consideration of Navy Yard Design, Location, Capacity and Maintenance, with Plan and Description of a Large, Efficient Yard Properly Located," by Captain L. S. Van Duzer, U. S. Navy, Associate.

To illustrate paper on "General Consideration of Navy Yard Design, Location, Capacity and Maintenance, with Plan and Description of a Large, Efficient Yard Properly Located," by Captain L. S. Van Duzer, U. S. Navy, Associate.



NOTE:- R. R. TRACKS SHOWN BY DOT & DASH LINES
CRANE TRACKS SHOWN BY DOTTED LINES
SCALE:- 1/12" = 100 FEET

To illustrate paper on "Notes on the Performance of the S. S. Tyler," by E. H. Rigg, Esq., Member.

Fig. 1.—S. S. Tyler. Full Speed; Bow Wave.

Fig. 2.—S. S. Tyler. Full Speed; Bow Wave; Looking Down.

To illustrate paper on "Notes on the Performance of the S. S. Tyler," by E. H. Rigg, Esq., Member.

FIG. 3.—S. S. TYLER. FULL SPEED; BOW WAVE; LOOKING DOWN.

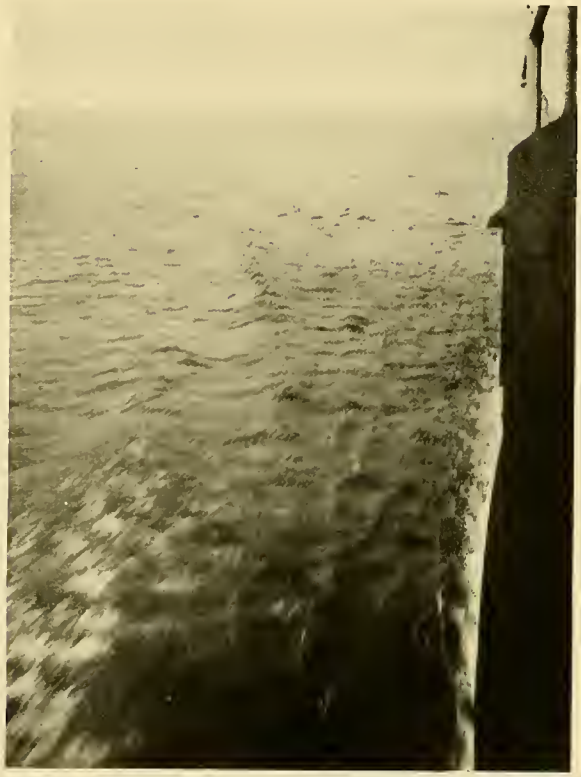


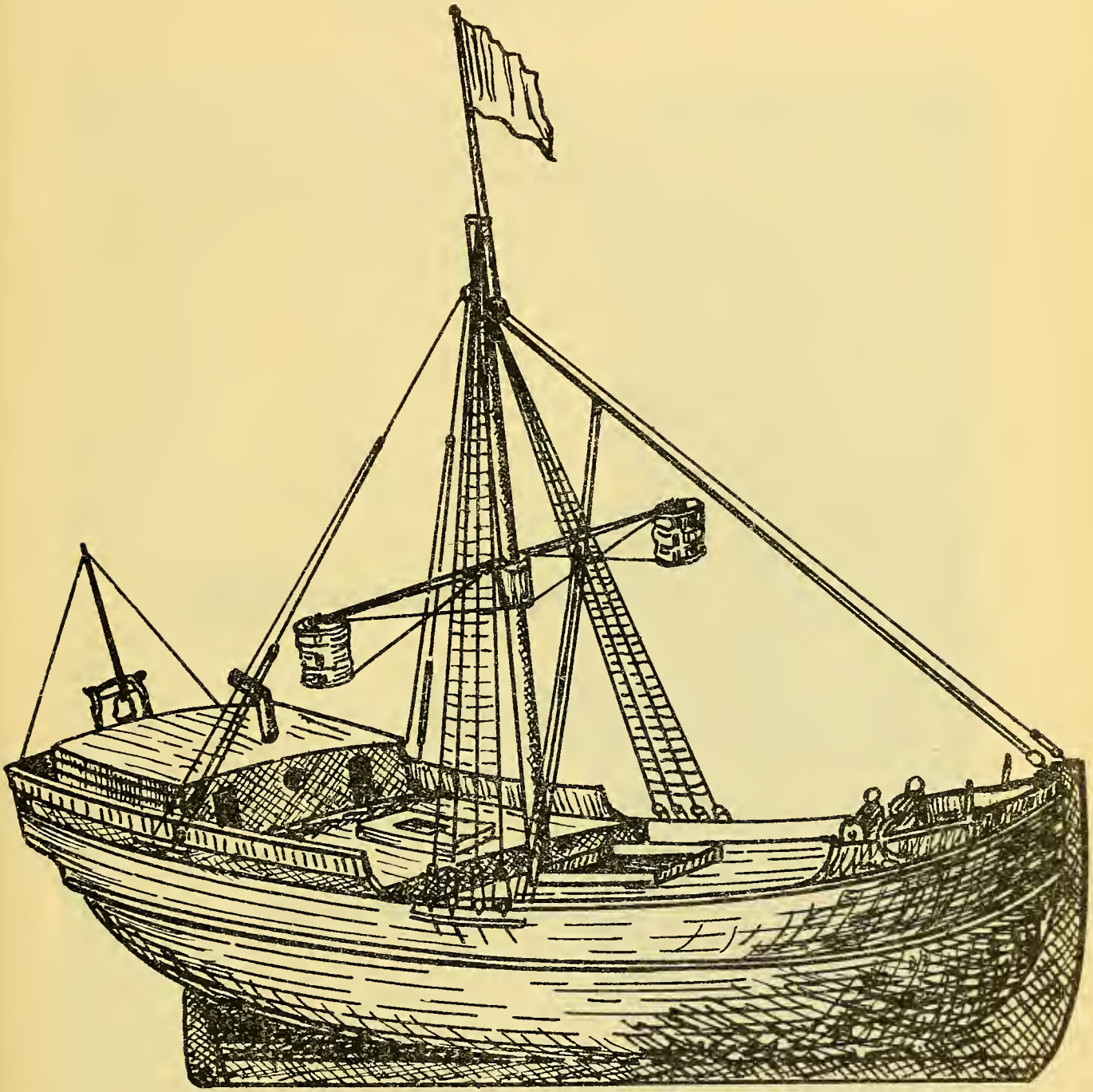
FIG. 4.—S. S. TYLER. FULL SPEED. TAKEN FROM UNDER BRIDGE, LOOKING AFT.

To illustrate paper on "Notes on the Performance of the S. S. Tyler," by E. H. Rigg, Esq., Member.

Fig. 5.—S. S. Tyler. Full Speed; Stern Wave.

Fig. 6.—S. S. Tyler. Full Speed. Taken from Starboard Quarter.

To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.



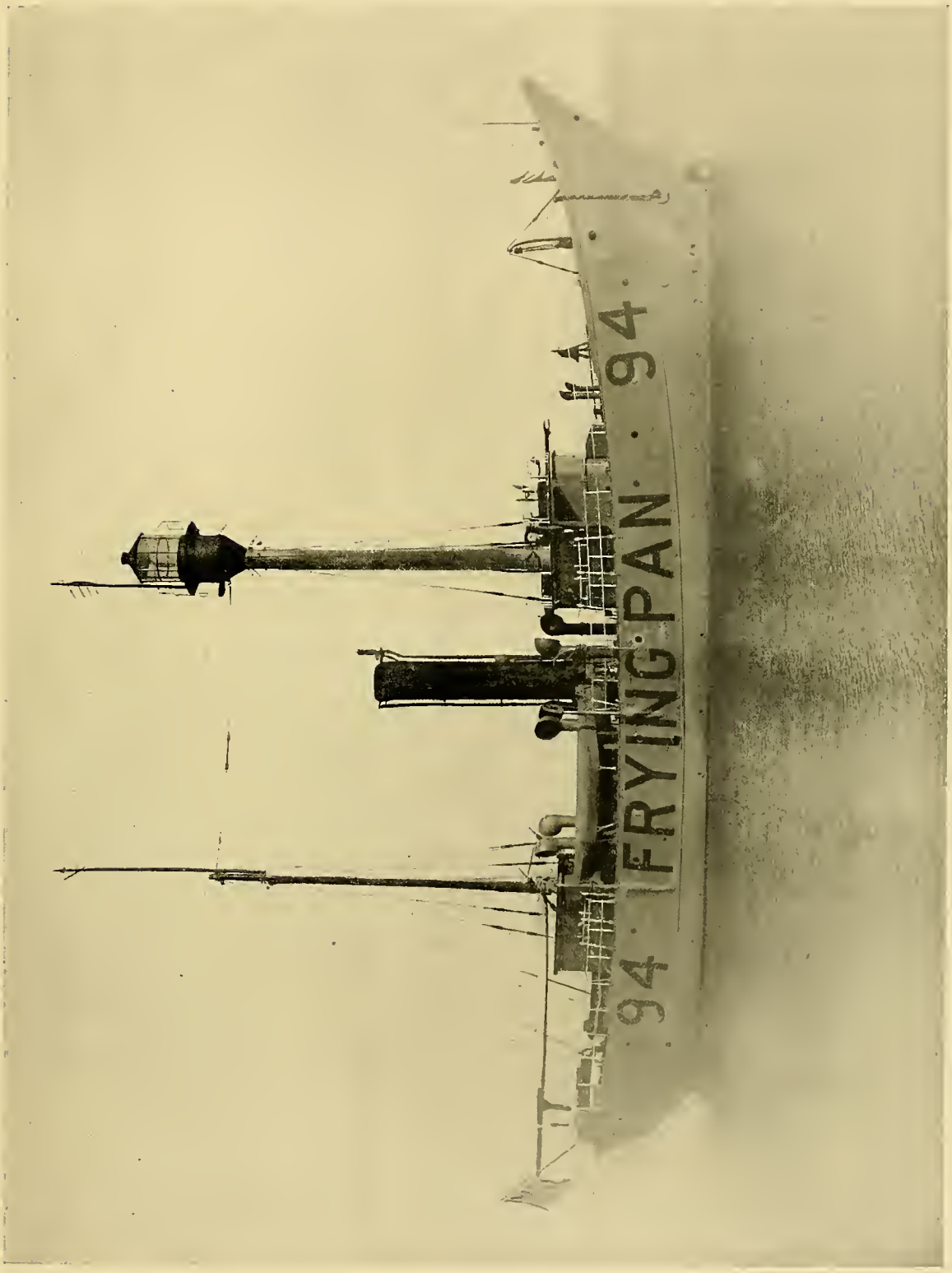
THE FIRST LIGHTSHIP - 1732.

NORE SANDS - ENGLAND.

THE NORRIS PETERS CO., WASHINGTON, D. C.

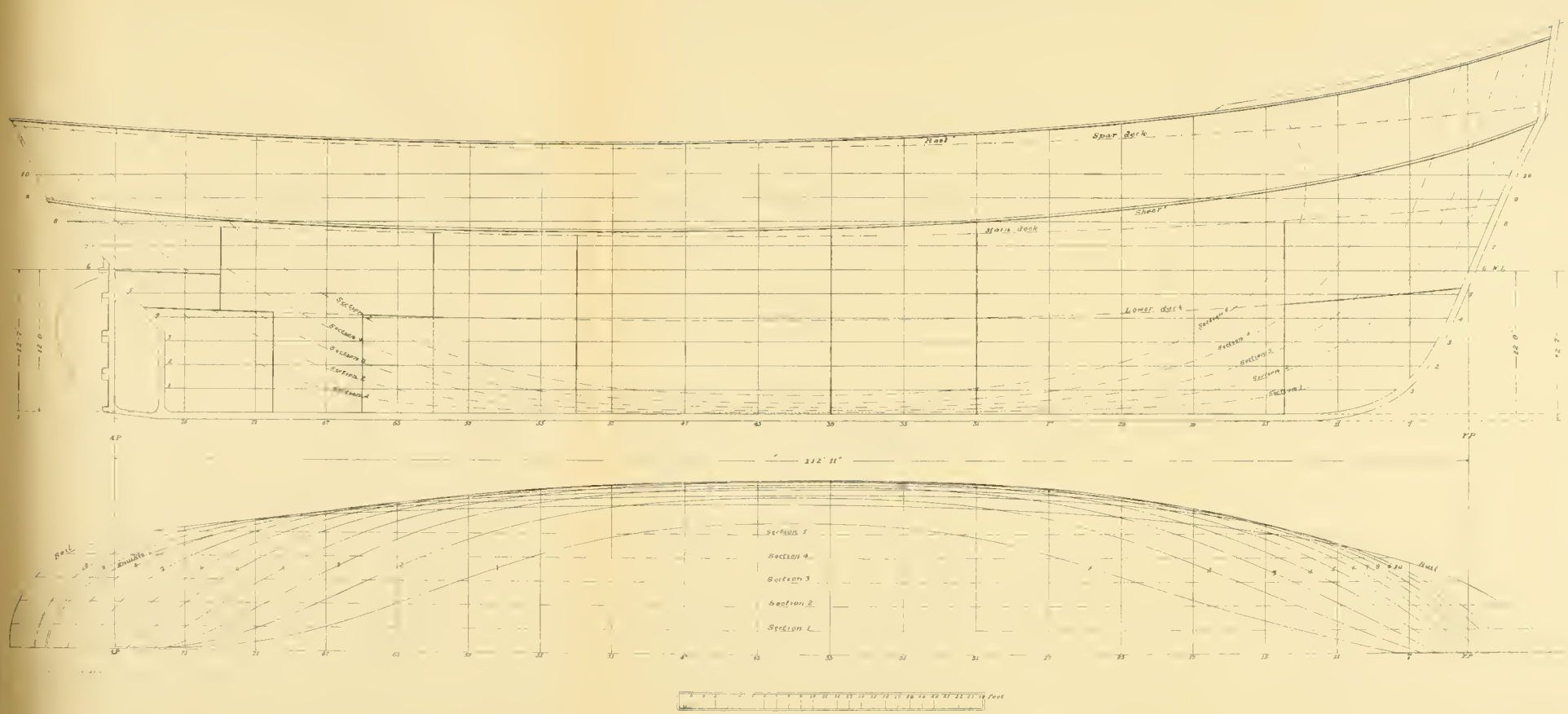
From HARDY

To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.

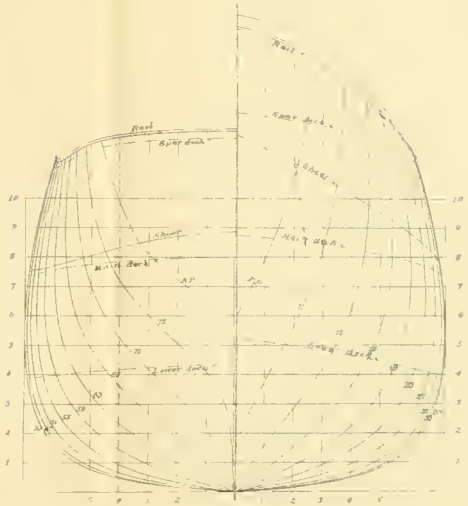


U. S. Lightvessel, No. 94, Frying Pan, Stationed Off Cape Fear, N. C.

To illustrate paper on "The Evolution of the Lightship,"
by George Crouse Cook, Esq.

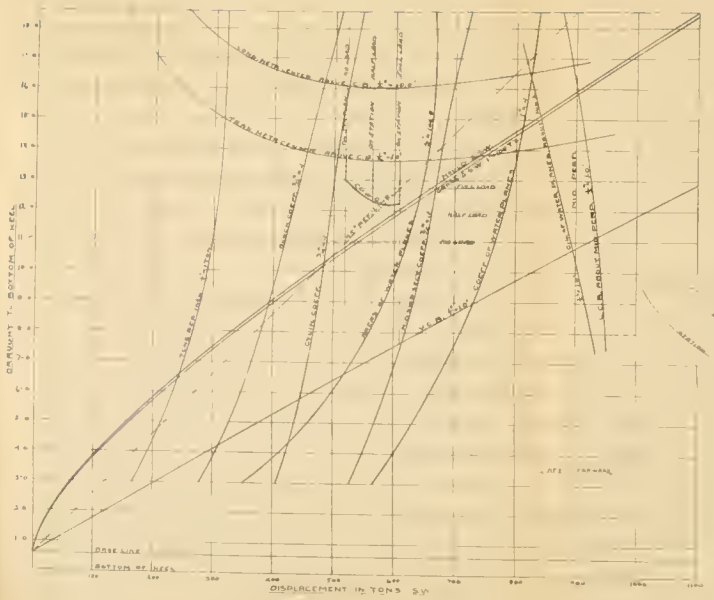


Length between perpendiculars	112' 11"
Beam, molded	29' 0"
Depth, top of keel to top of maindeck beam	15' 4"
Displacement at 12' 9" draft	660 tons



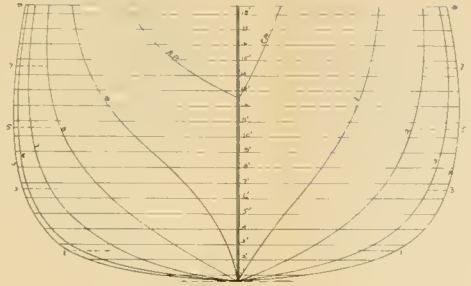
To illustrate paper on "The Evolution of the Lightship,"
by George Cronse Cook, Esq

BONJEAN, DISPLACEMENT & OTHER CURVES.
LIGHT-VESSEL No 94

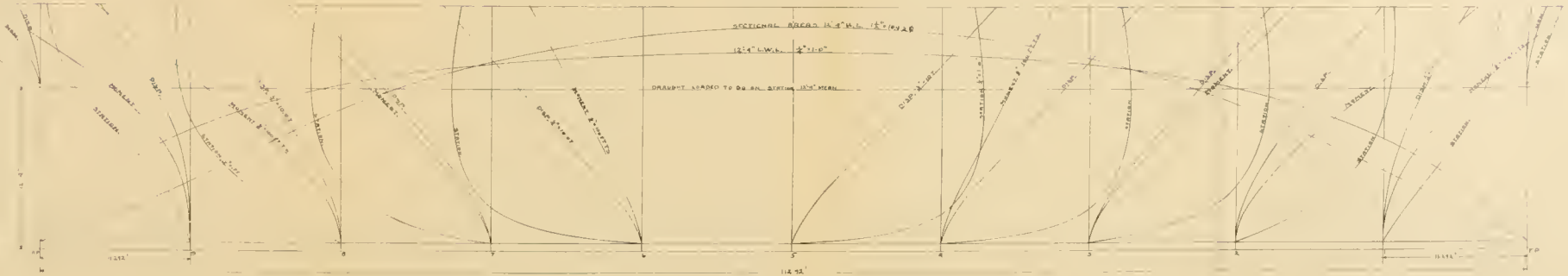


SCALES FOR BONJEAN CURVES.

DISPLACEMENT	1/4" = 10 TONS
MOMENT	1/8" = 100 FT. "
STATION HALF BREADTH	1/4" = 1'-0"
DRAUGHT	1/4" = 1'-0"
LENGTH	1/4" = 1'-0"



DISP BODY PLAN
SCALE 1/4" = 1'-0"



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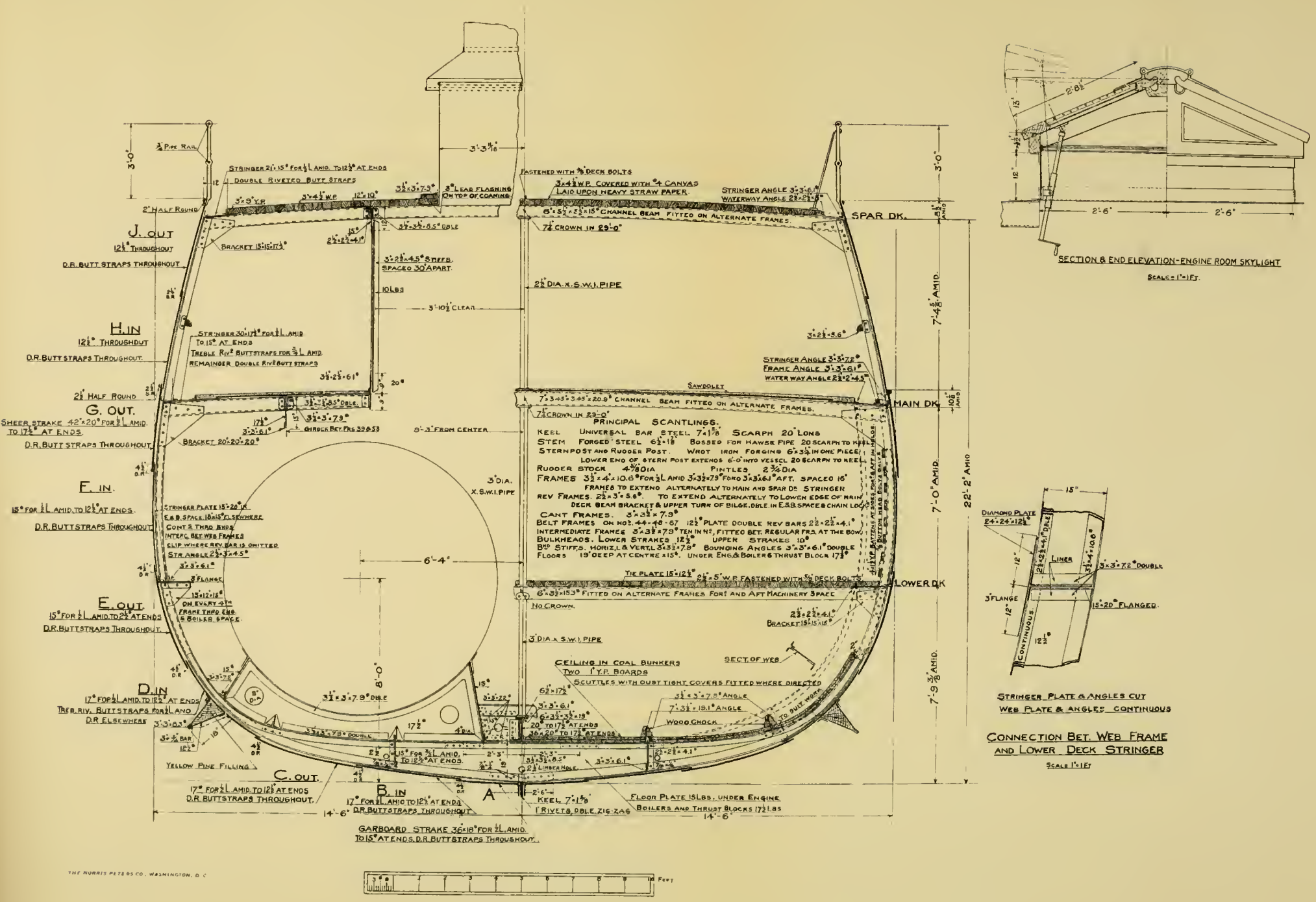

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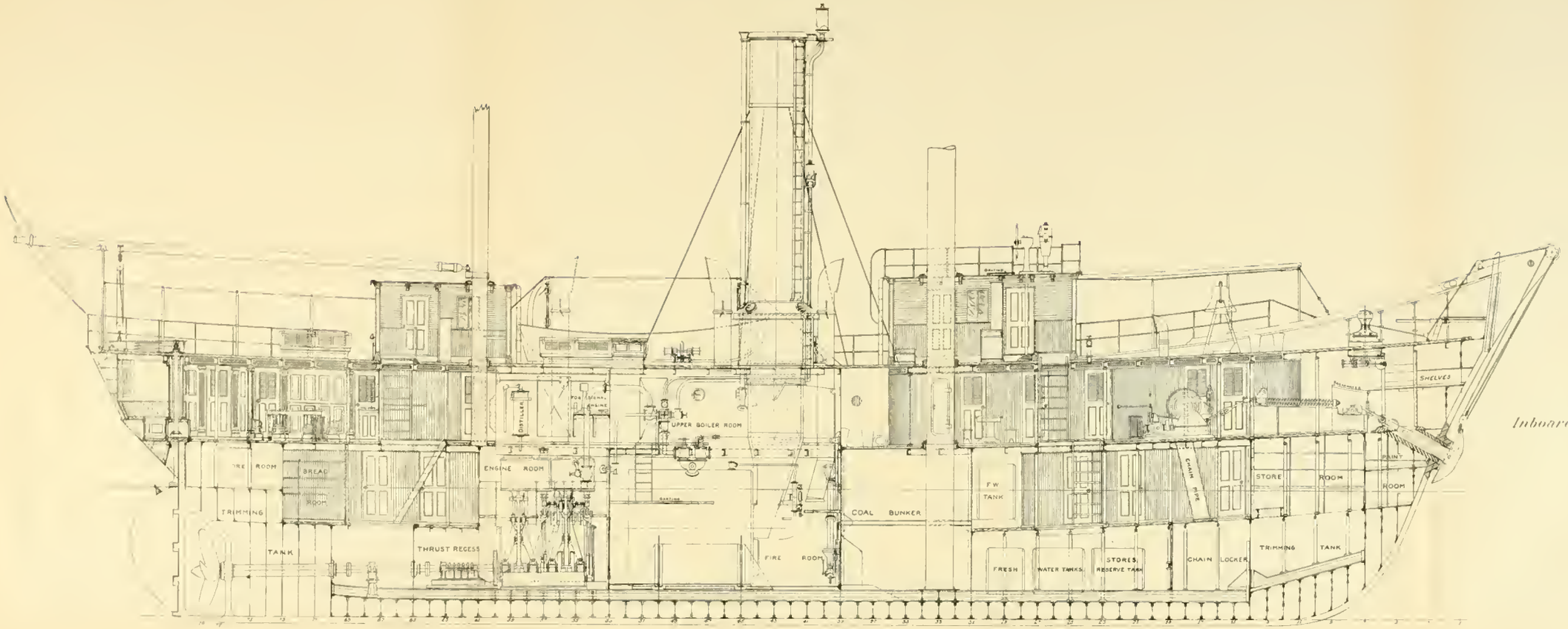
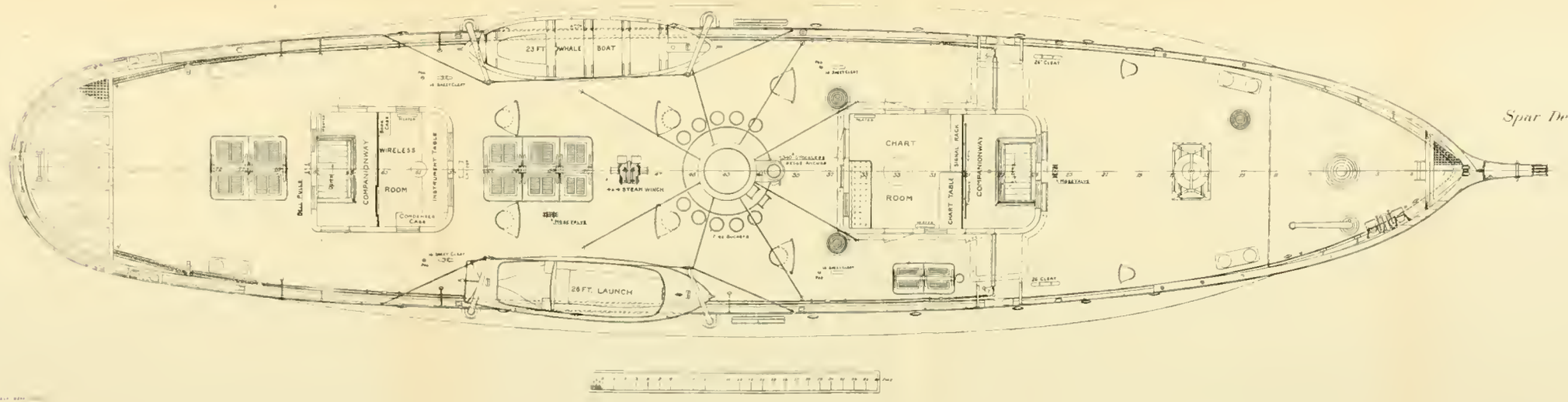
To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.

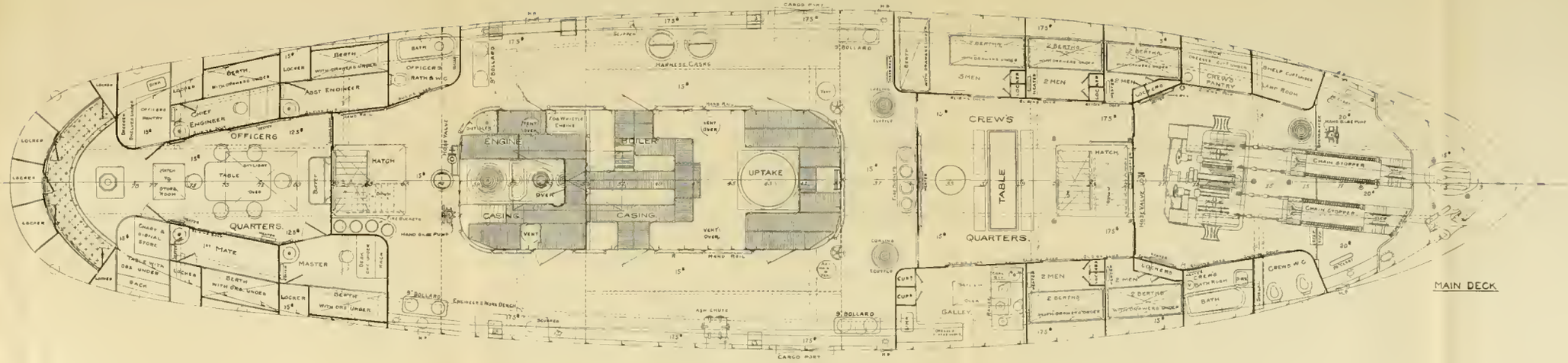


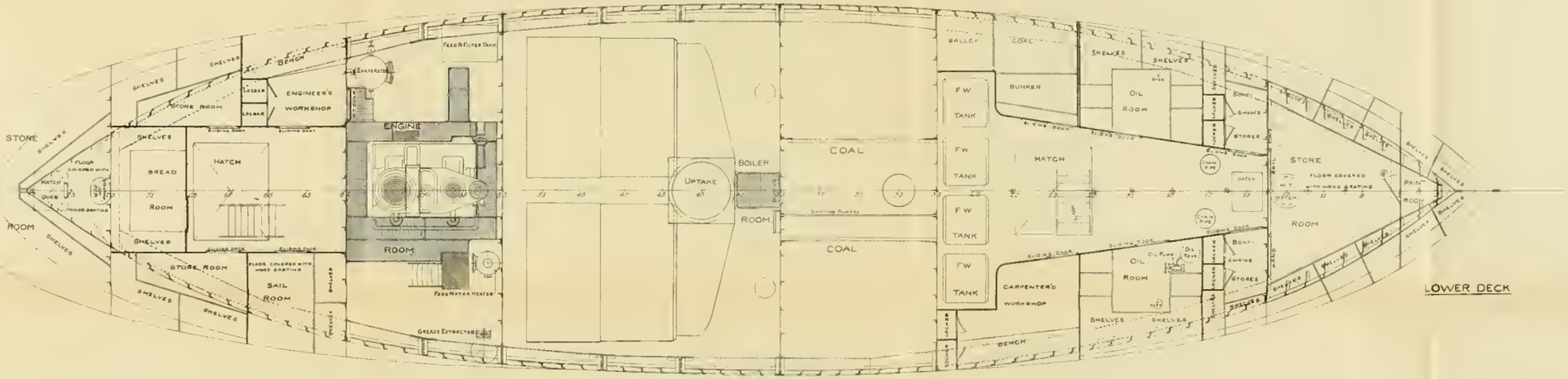
Inboard Profile.

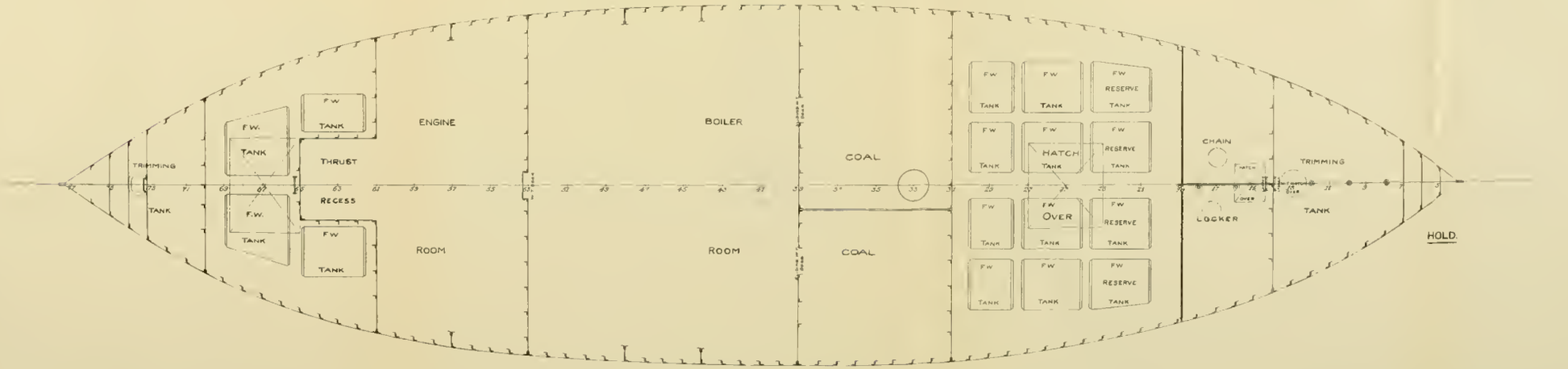


Spar Deck

To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.







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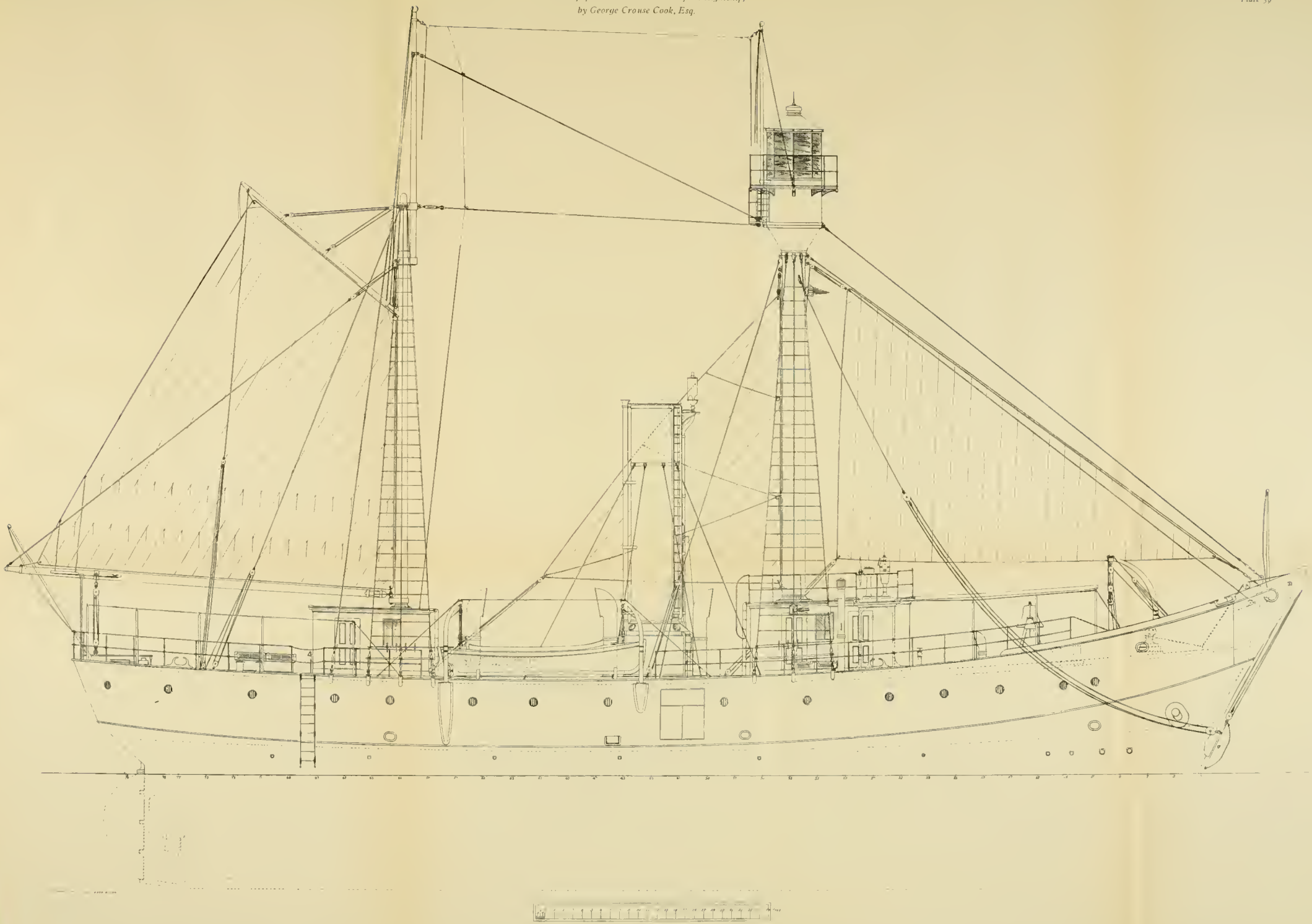

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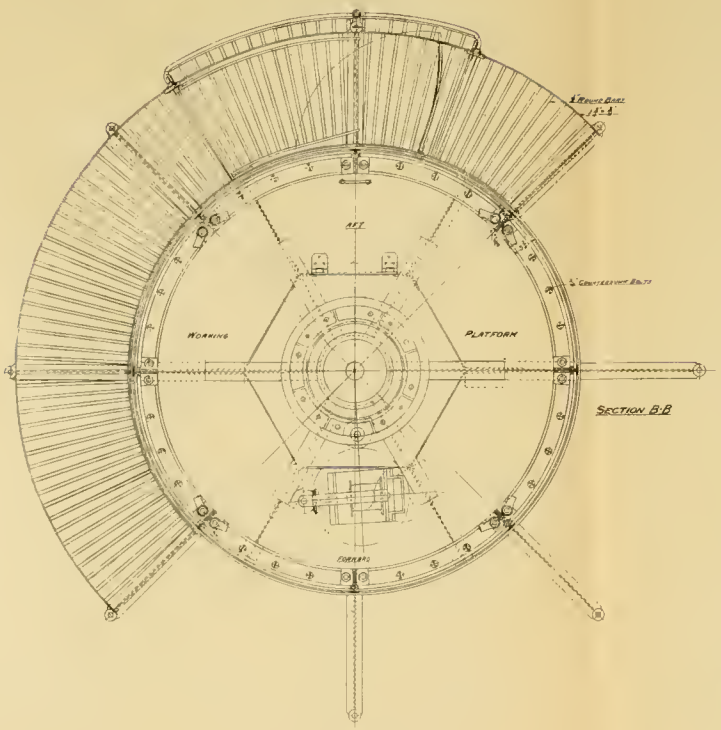

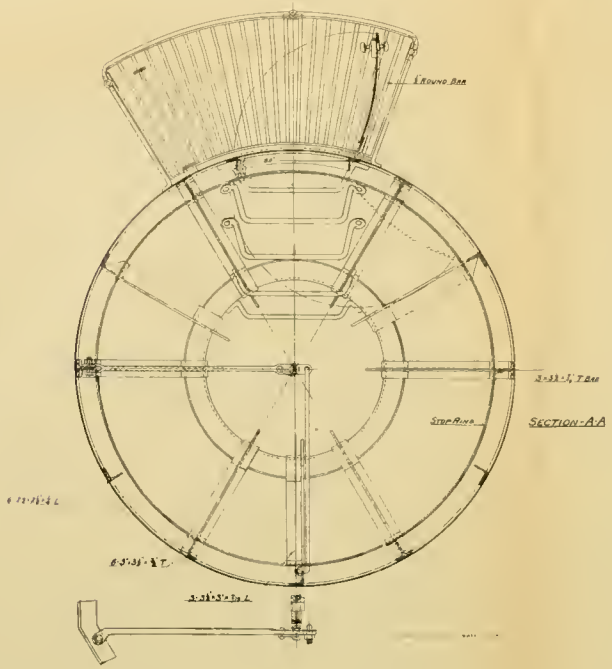

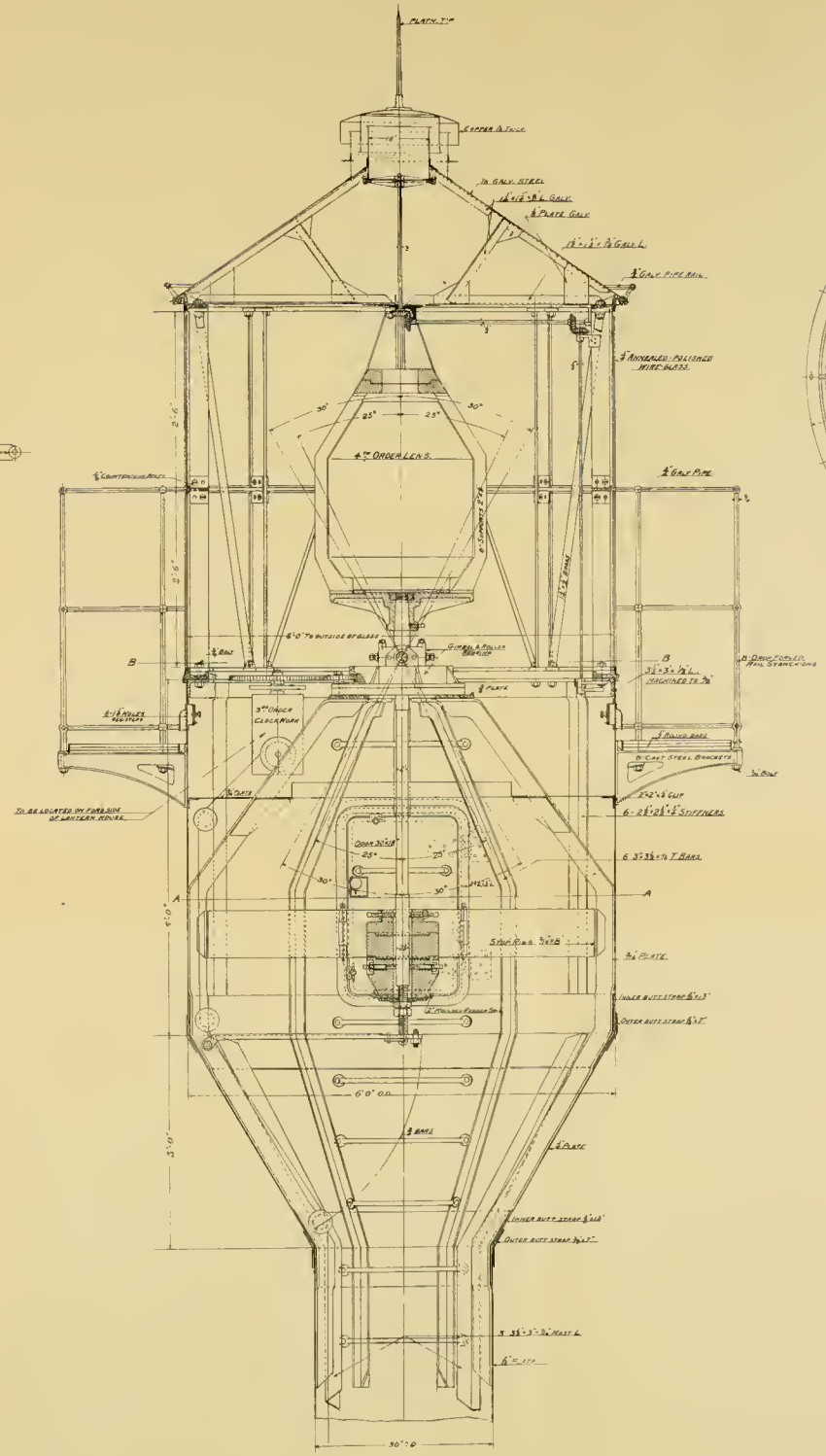

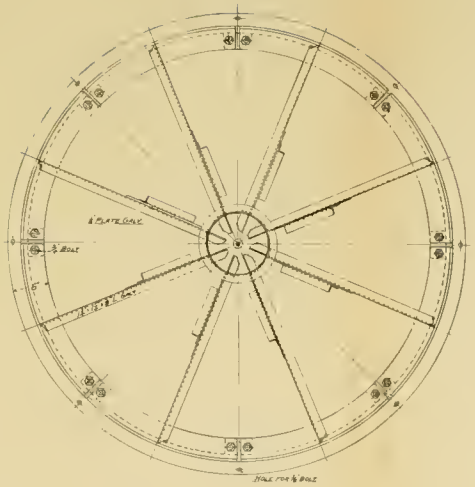

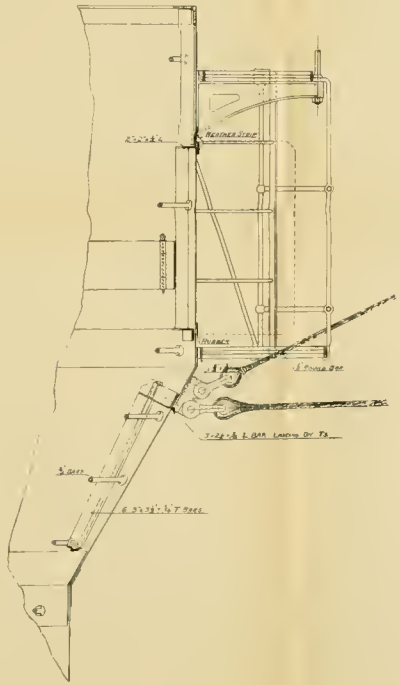

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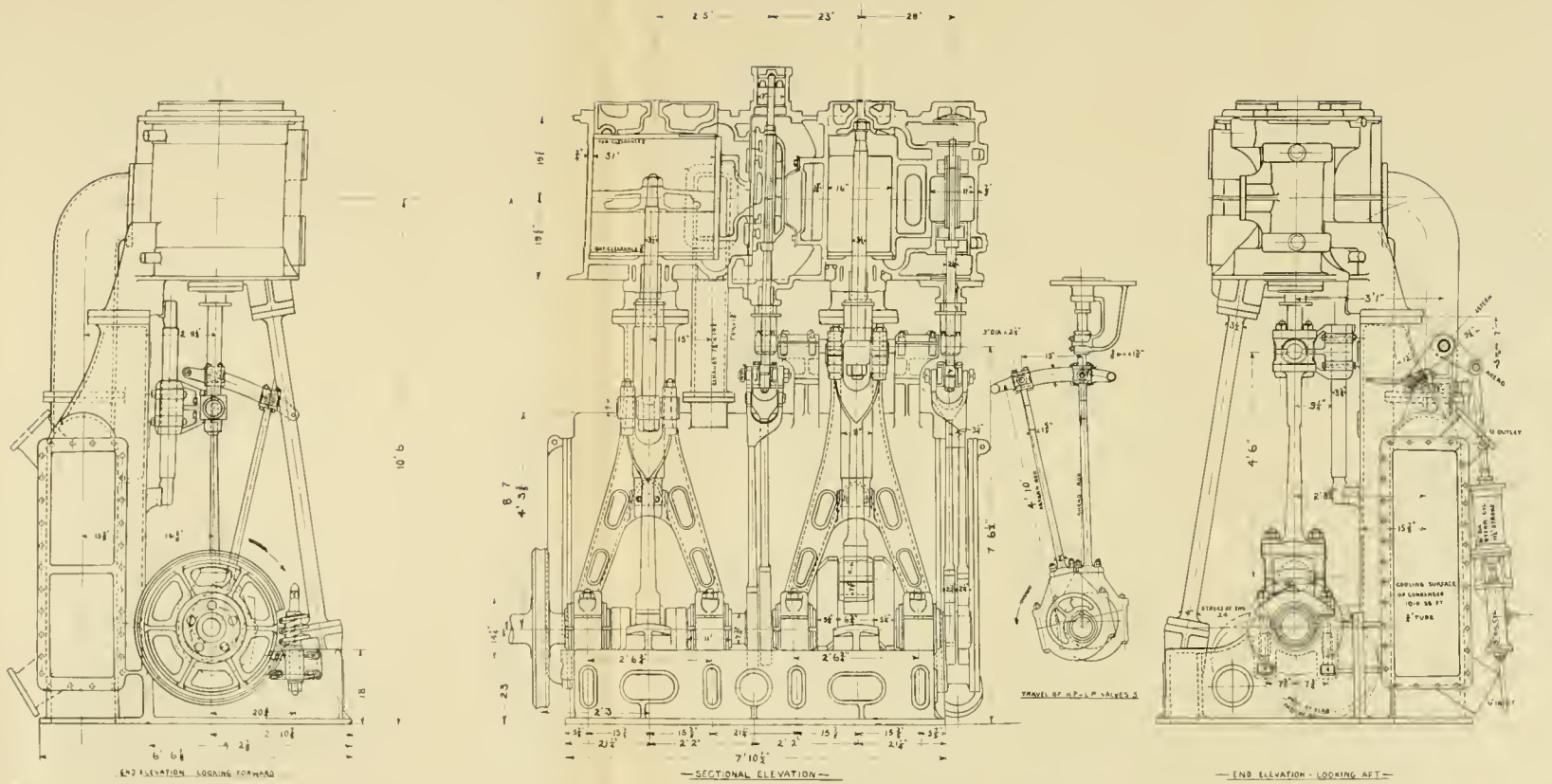
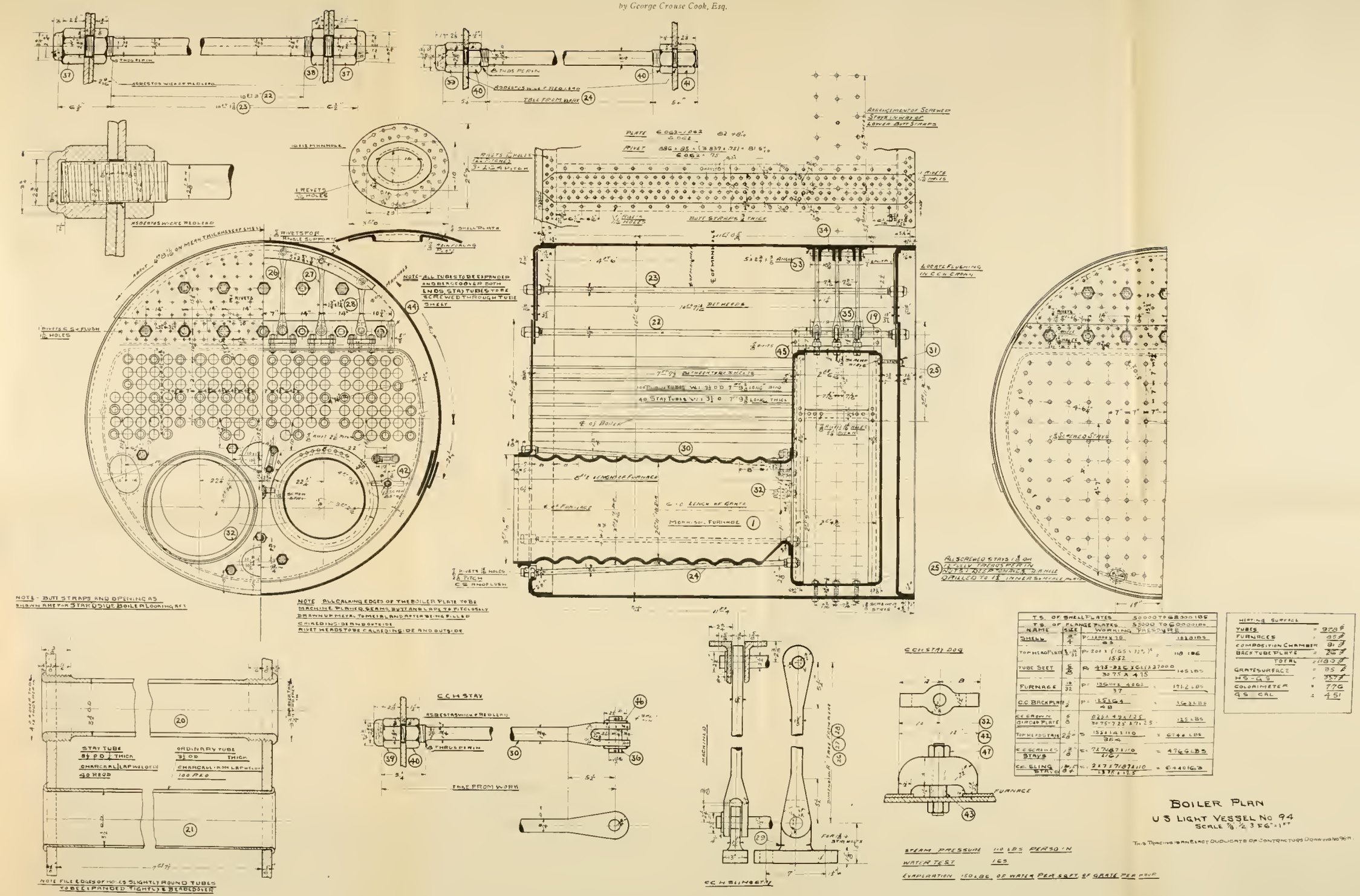


ARRANGEMENT OF MAIN ENGINE $\frac{16 \times 31}{24}$

U.S. LIGHT VESSEL No 94
SCALE 1" = 1 FT

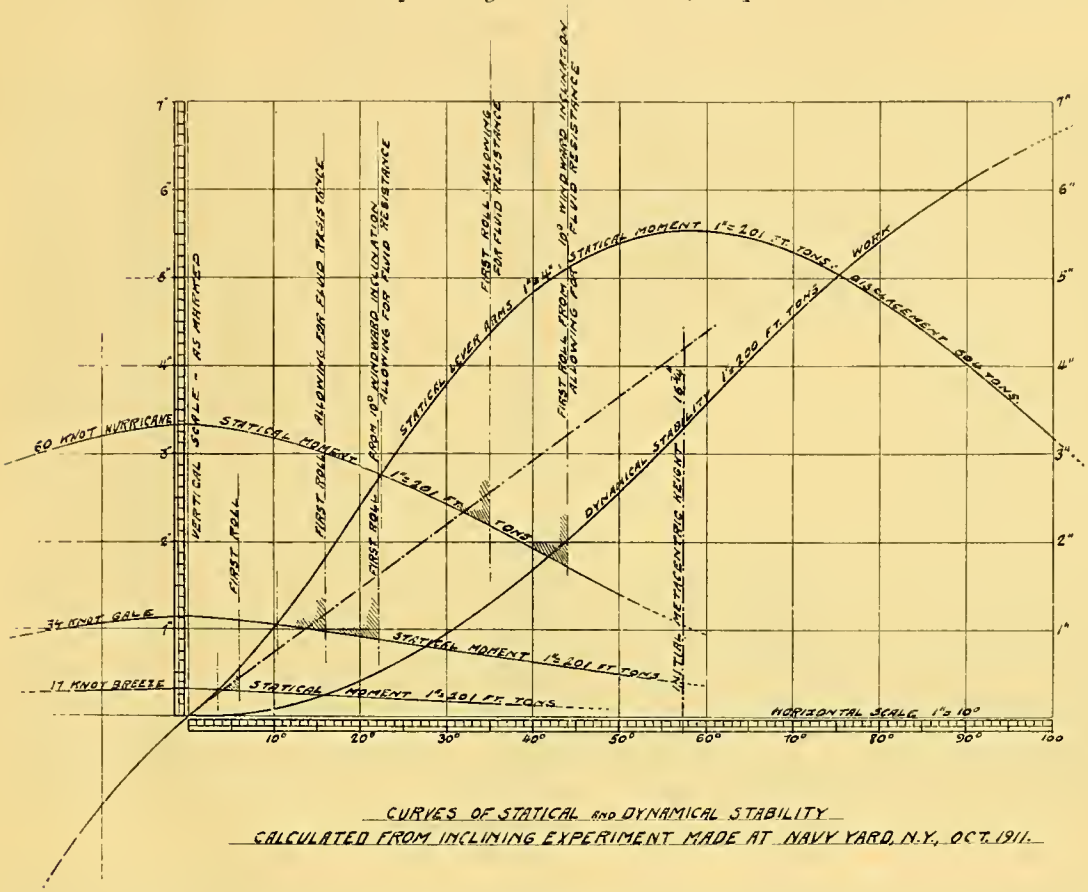
To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.



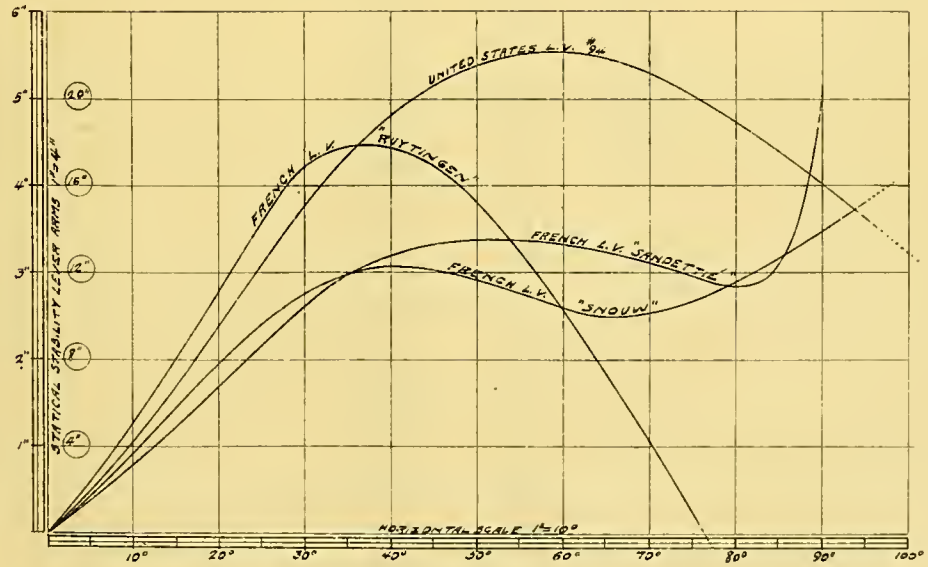
NAME	SIZE	WORKING PRESSURE	
T.S. OF SHELL PLATES		50000 TO 68000 LBS	
T.S. OF FLANGE PLATES		55000 TO 60000 LBS	
SHELL	15/16	P = 1200 × 16 / 63	142 LBS
TOP HEAD PLATE	13/32	P = 200 × (165 × 12.5)^½ / 15.52	118 LBS
TUBE SHEET	5/8	R = 4.75 - 2.2 C (165 × 27000) / 30.75 × 4.15	145 LBS
FURNACE	13/32	P = 150 × 0.4861 / 37	171.2 LBS
C.C. BACK PLATE	1/2	P = 15.1164 / 48	163 LBS
C.C. CROWN CIRCLE PLATE	5/8	0.625 × 4.96 × 125 / 30.75 - 7.25 × 1.71 × 2.5	125 LBS
TOP HEAD STAYS	2 1/8	= 1532 × 143 × 110 / 324	= 6144 LBS
C.C. SCREWED STAYS	1 1/8	= 7.74 × 0.7854 × 110 / 1.767	= 4766 LBS
C.C. SLING STAYS	1 5/8 / 1 3/4	= 2.4757 × 0.7854 × 110 / 1.578 × 1.23	= 6440 LBS

HEATING SURFACE		
TUBES	=	970 ☐'
FURNACES	=	95 ☐'
COMPOSITION CHAMBER	=	91 ☐'
BACK TUBE PLATE	=	76 ☐'
TOTAL	=	1130 ☐'
GRATE SURFACE	=	35 ☐'
H.S. - G.S.	=	32.3 ☐'
CALORIMETER	=	776
G.S. CAL	=	451

To illustrate paper on "The Evolution of the Lightship," by George Crouse Cook, Esq.



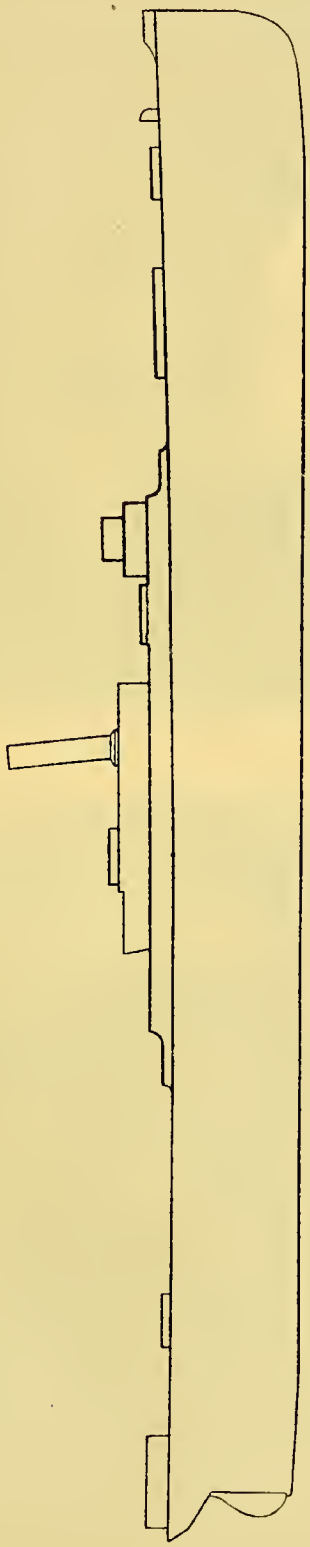
CURVES OF STATICAL AND DYNAMICAL STABILITY
CALCULATED FROM INCLINING EXPERIMENT MADE AT NAVY YARD, N.Y., OCT. 1911.



COMPARISON OF STATICAL STABILITY LEVER ARMS
UNITED STATES L.V. #94 AND FRENCH L.V.S. "RUYTINGEN," "SANDETTIE," AND "SNOUW."

THE NORRIS PETERS CO., WASHINGTON, D.C.

To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.



Outboard Profile of S. S. Ancon.

To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.

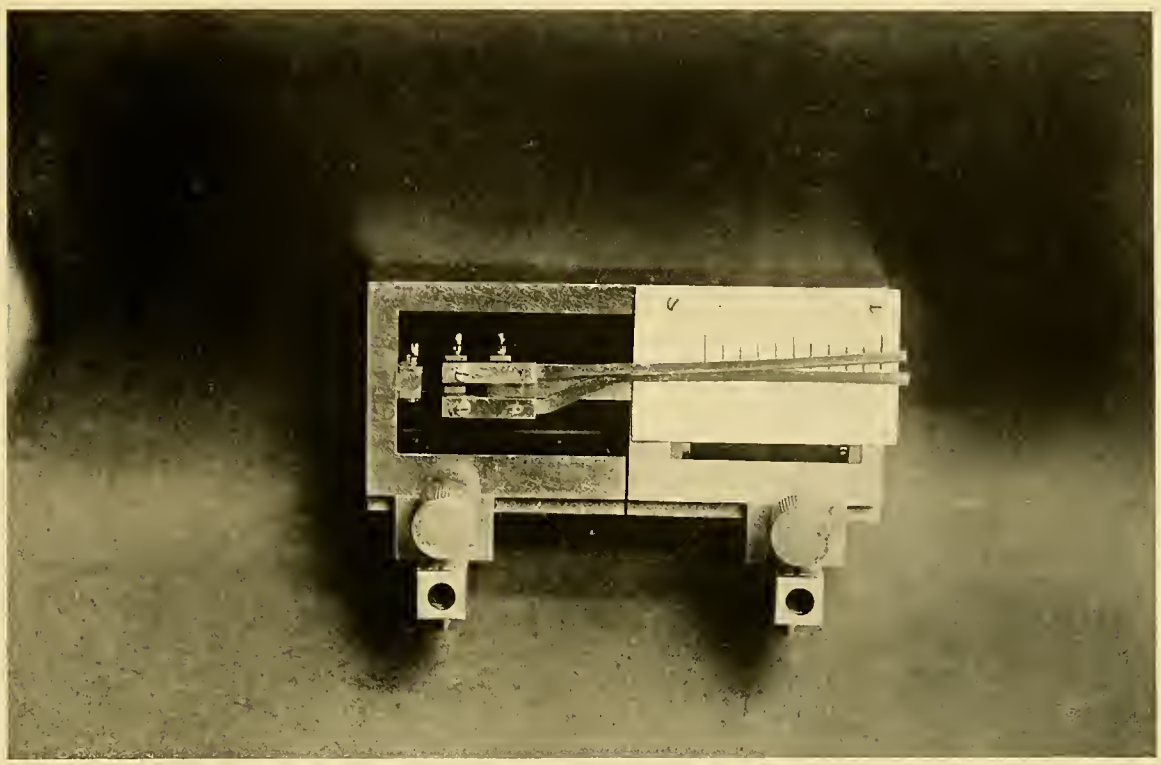


Fig. 1.—Scissors Gauge.

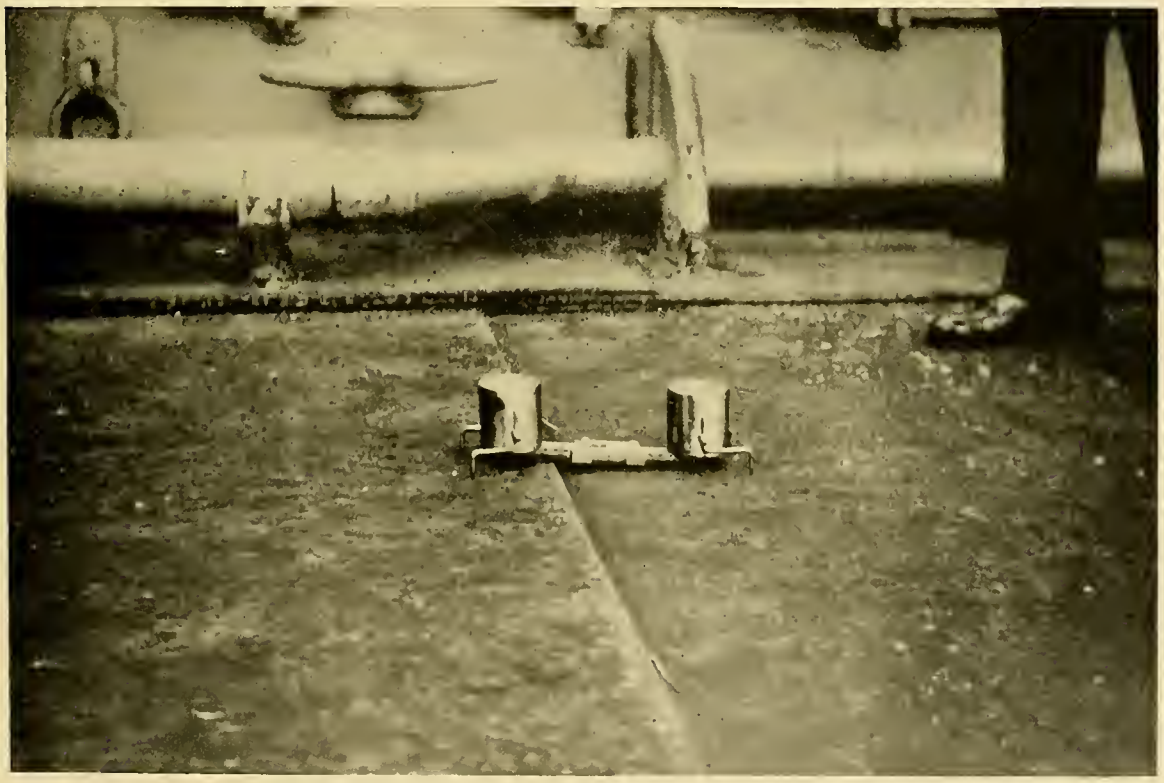


Fig. 2.—Scissors Gauge Applied to the Deck Plates of S. S. Ancon, Spanning a Lap Joint.

To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.

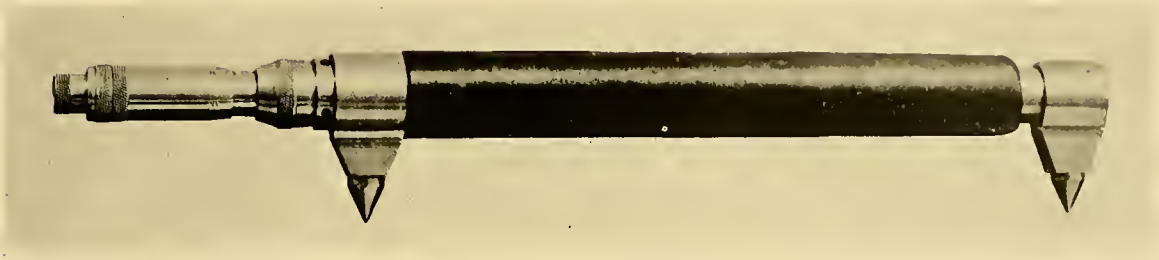


Fig. 3.—Strain Gauge.

Fig. 4.—Place where Maximum Strains Were Observed, on Angle of Bulwark Rail, Indicated by * on the Figure.

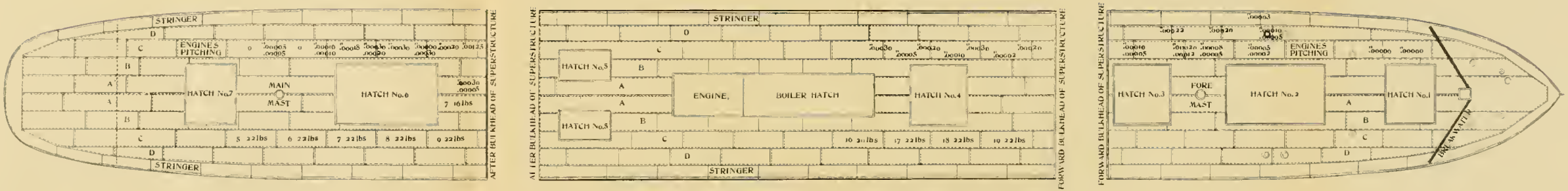
To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq

S.S. ANCON, SHELTER DECK.

MEASURED STRAINS. EFFECTS OF ENGINES ON DECK PLATING, SMOOTH SEA.

GAUGED LENGTHS, 6 INCHES EACH.

FULL CARGO.



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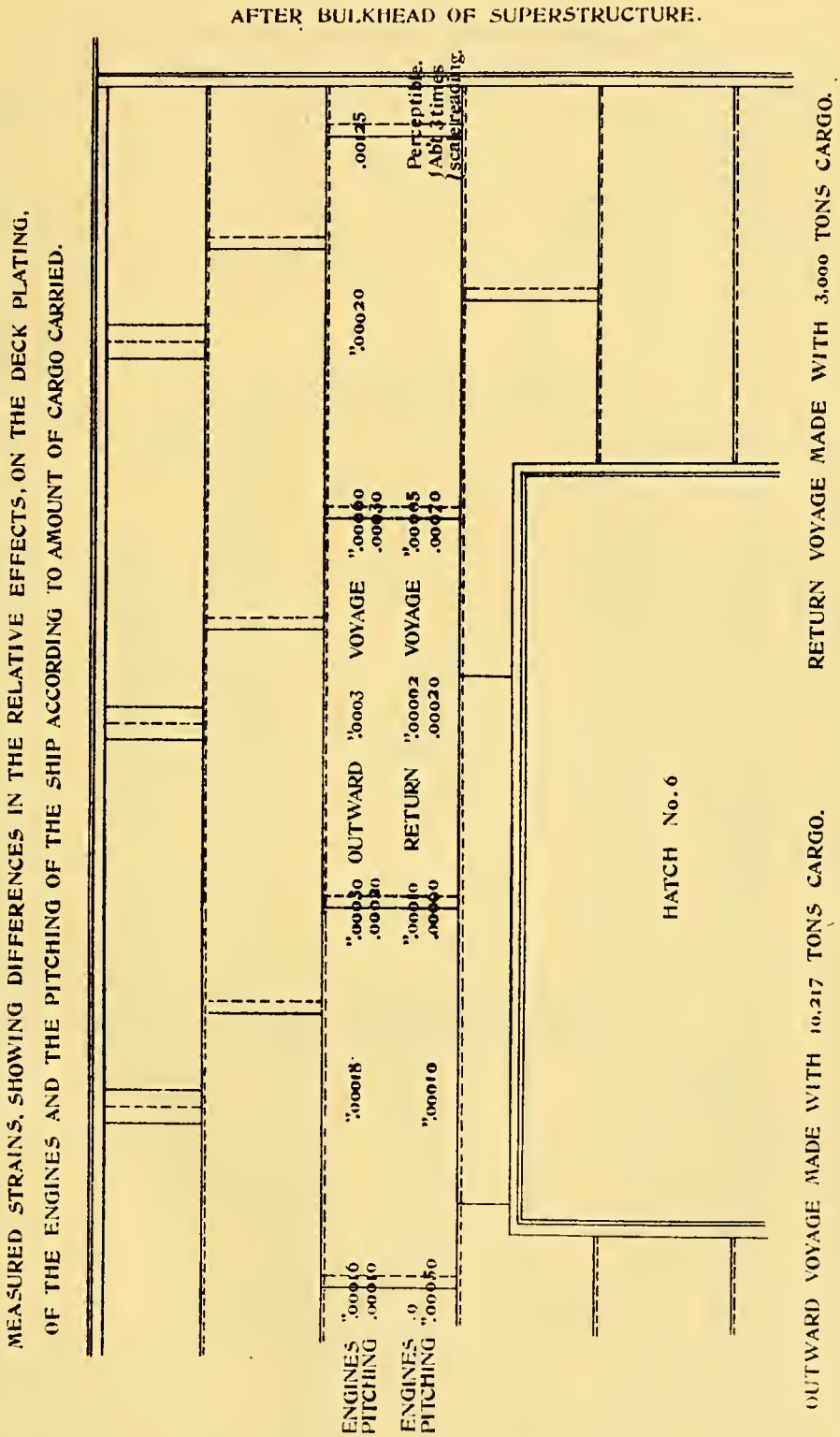
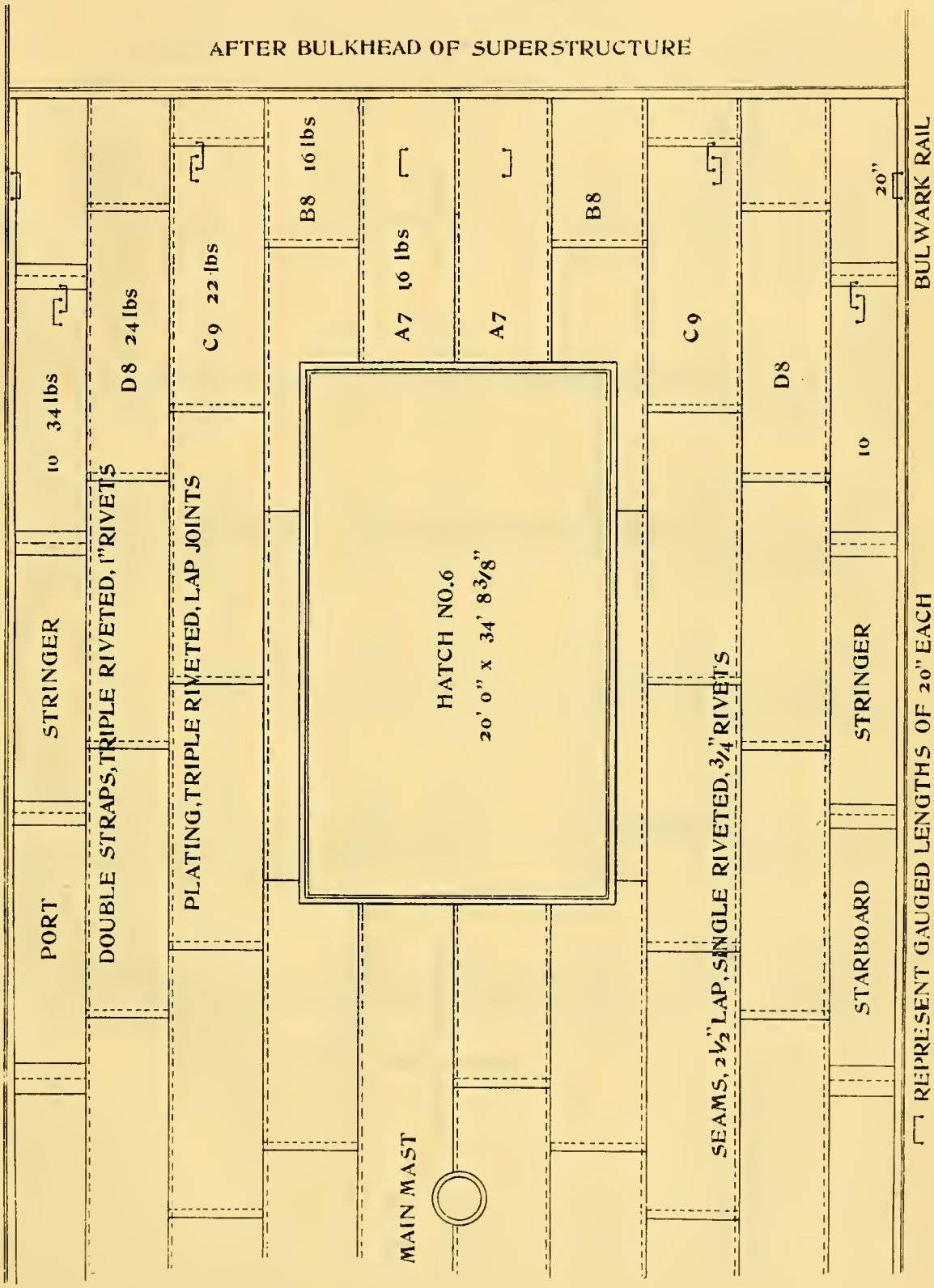


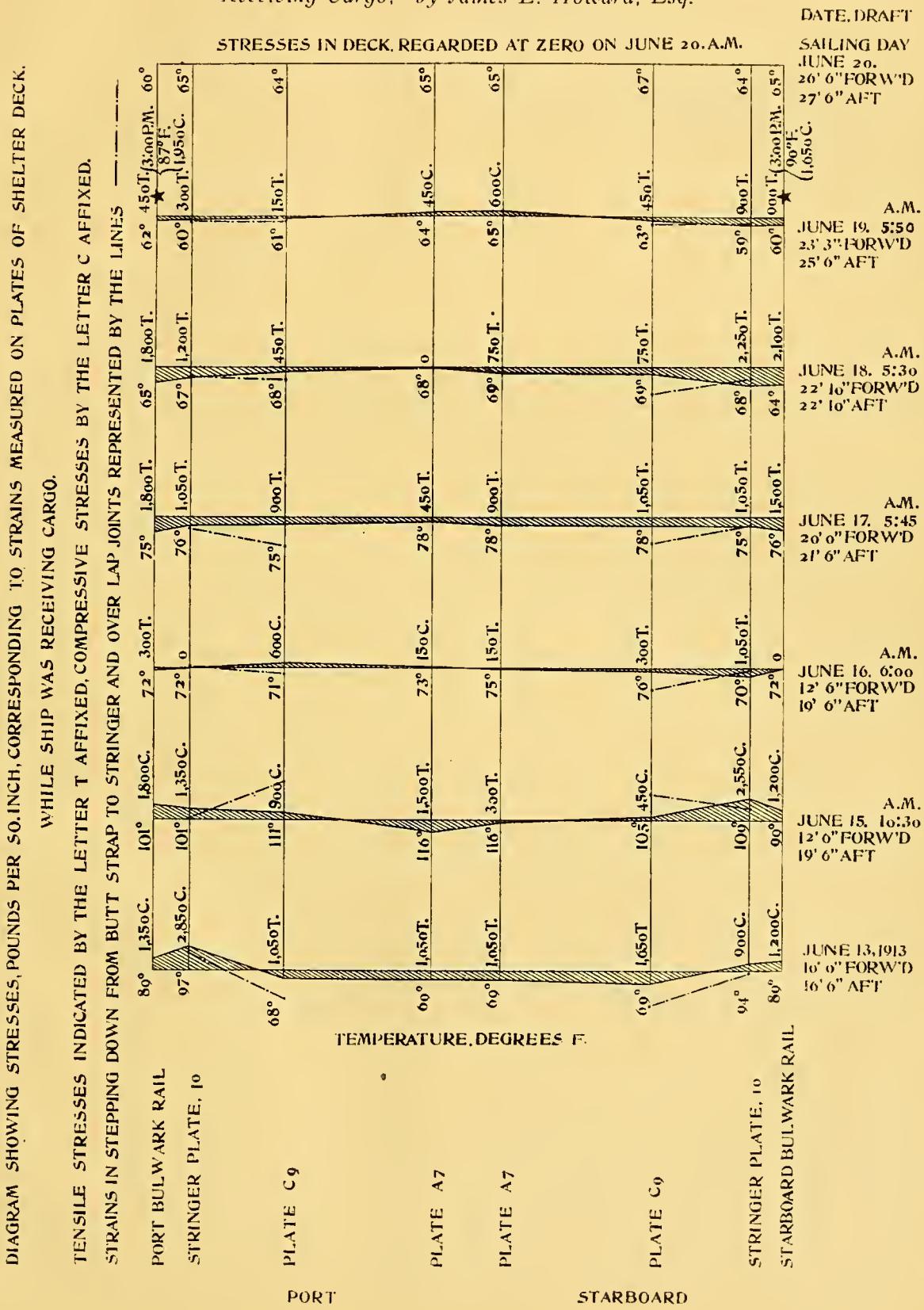
To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.

S.S. ANCON

STRAIN GAUGE MEASUREMENTS ON PLATES OF SHELTER DECK, MADE WHILE RECEIVING CARGO



To illustrate paper on "Strains in the Hull of a Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.



To illustrate paper on "Strains in Hull of Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.

Table 1

S. S. ANCON

Strain in Plates of Shelter Deck of Ship When at Sea.

10,217 tons cargo. Draft about 39 feet.

Measurements with scissors gauge, lengths of 8 inches each, on deck plating, port side of ship, on outward trip, New York to Colon, April 1913.

Observations on plates at middle of width and length, also stepping down from one plate to another, across triple-riveted lap joints.

Position of ship, off easterly end of Cuba. Smooth sea.

Course of Plating	Plate: No. of	Plate: Weight of, lbs.	Gauged Length: Location of	On solid plate or joint	Measured Strain	Corresponding stress lbs. per sq. in.	Probable effect of: Engines	Probable effect of: Pitching
Forward Part of Ship.								
C	27	22	Just aft breakwater	Solid plate	No strain detected			
"	26 to 27	32	Abreast Hatch No. 1, just aft breakwater	Joint	".00006			
"	26	22	" " " 1	Solid plate	No strain detected			
"	25 to 26	22	" " " 1	Joint	.00006			
"	25	22		Solid plate	.00003			
"	24 to 25	22		Joint	.00012			
"	24	22	Abreast Hatch No. 2	Solid plate	.00002	100		
"	23	32	" " " 2	Solid plate	.00007	350	".00005	.00002
"	22 to 23	22	" " " 2	Joint	.00015		.00010	.00005
"	22	22	" fore mast	Solid plate	.00013	650	.00008	.00005
"	21 to 22	22	" " "	Joint	.00032		.00020	.00012
"	21	22	" Hatch No. 3	Solid plate	.00005	250	.00003	.00002
"	20 to 21	22	" " " 3	Joint	.00015		.00010	.00005
"	20	22	Just aft forward bulkhead of superstructure	Solid plate	.00002	100	.00002	0
"	19 to 20	22	Aft forward bulkhead of superstructure	Joint	.00020		.00020	0
"	19	22	" " " " "	Solid plate	.00002	100	.00002	0
"	18 to 19	22	Abreast forward end Hatch No. 4	Joint	.00030		.00030	
"	18	22	Abreast Hatch No. 4	Solid plate	.00010	500	.00010	
"	17 to 18	22	" " " 4	Joint	.00020		.00020	
"	17	22	Abreast, after end Hatch No. 4	Solid plate	.00005	250	.00005	
"	16 to 17	22	Just forward of boiler hatch	Joint	.00030		.00030	
D	23 to 24	22	Abreast forward end Hatch No. 2	Joint	.00006		.00010	.00005
"	22 to 23	22	Abreast Hatch No. 2	"	.00015		.00020	
"	21 to 22	22	" after end Hatch No. 2	"	.00020		.00022	
"	20 to 21	22	" forward end Hatch No. 3	"	.00022			
Stringer	Butt strap to 25	30	" Hatch No. 2	"	.00003			
"	Butt strap to 24	32	" " " 2	"	.00003			
Stringer angle	23	22	" " " 2	Solid angle	.00002	100		
After Part of Ship.								
C	9 to 10	22	Just aft, after bulkhead of superstructure	Joint	About ".00125		About ".00125	
"	9	22	Aft, after bulkhead of superstructure	Solid plate	.00020	1000	.00020	
"	8 to 9	22	Abreast forward end Hatch No. 6	Joint	.00090		.00050	.00030
"	8	22	Abreast Hatch No. 6	Solid plate	.00030	1500	.00030	
"	7 to 8	22	" " " 6	Joint	.00050		.00030	.00020
"	7	22	" " " 6	Solid plate	.00018	900	.00018	
"	6 to 7	22	" after end Hatch No. 6	Joint	.00026		.00016	.00010
"	6	22	Nearly abreast main mast	Solid plate	No strain detected			
"	5 to 6	22	Abreast main mast	Joint	.00010		.00005	.00005
"	5	22	Just forward of Hatch No. 7	Solid plate	No strain detected			
B	8	16	Just aft, after bulkhead of superstructure	Solid plate	.00045	2250	.00045	
A	7	16	" " " " " "	" "	.00035	1750	.00030	.00005
Stringer	Butt strap to 10	34	Aft, after bulkhead of superstructure	Joint	.00015		.00015	
Stringer angle			Abreast forward end Hatch No. 6	Solid angle	.00025	1250		
Bulwark rail			Aft, after bulkhead of superstructure	" "	.00026	1300		
Earlier Observations made when a Moderate Sea was Running. Position of Ship, off Watlins Island.								
C	8	22	Abreast Hatch No. 8 2 feet from coaming	Solid plate	".00050	2500		
D	8	22	Abreast forward end Hatch No. 6	Solid plate	.00070	3500		
"	7	22	Abreast Hatch No. 6	" "	.00060	3000		
Bulwark rail			Aft, after end of superstructure	" angle	.00110	5500		

To illustrate paper on "Strains in Hull of Ship at Sea and Those Measured While Receiving Cargo," by James E. Howard, Esq.

Table 2.

S. S. ANCON

Strains in Plates of Shelter Deck of Ship When at Sea.

3000 tons cargo. Draft 18' 4" forward, 19' 9" aft.

Measurements with soissors gauge, lengths of 6" each, on deck plating and bulwark rails, port side of ship, on return trip Colon to New York, May 1913

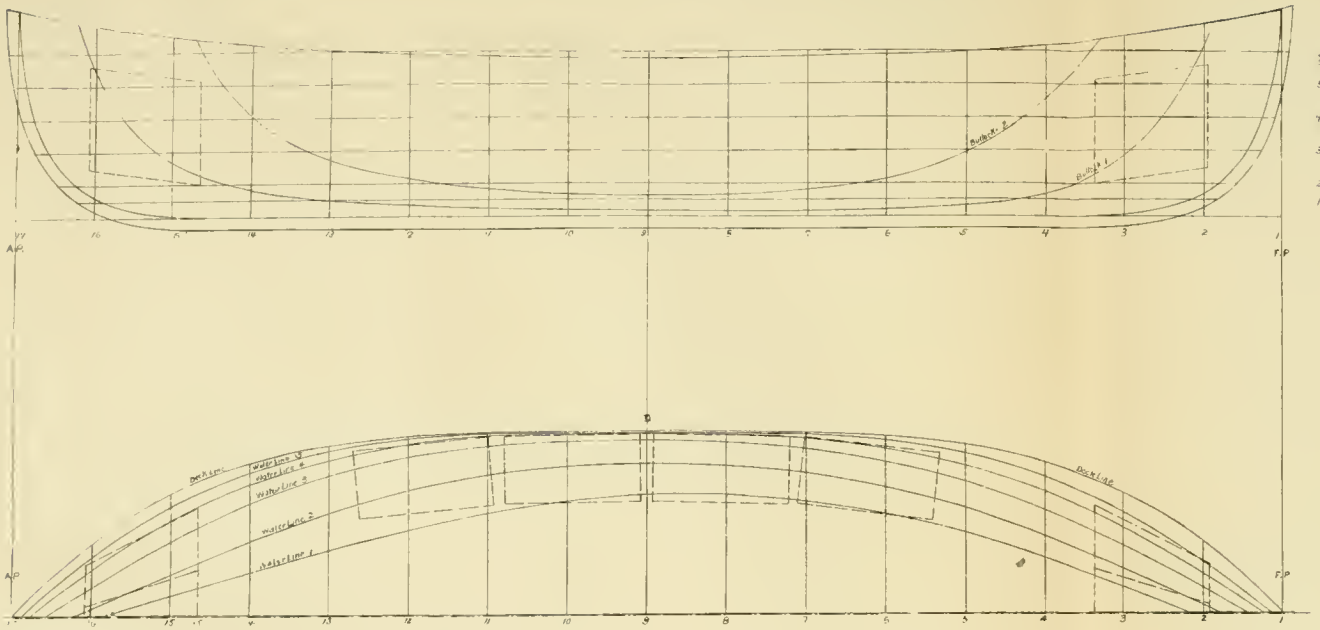
Observations on plates at middle of width and length, also stepping down from one plate to another, across triple-riveted lap joints.

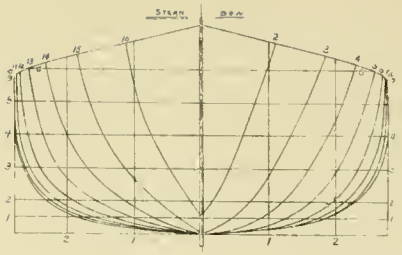
Light Sea.

	After Part of Ship.							
	Plate		Gauged Length				Probable effect of	
Course of Plating	No. of	Weight of, lbs.	Location of	On Solid plate or Joint	Measured Strain	Corresponding Stress lbs. per sq. in.	Engines	Pitching
C	9 to 10	22	Just aft, after bulkhead of superstructure	Joint	Estimated 3 times scale reading			".00300±
"	8 to 9	22	Abreast forward end Hatch No. 6	"	".00075		".00005	.00070
"	8	22	" Hatch No. 6	Solid plate	.00022	1100	.00002	.00020
"	7 to 8	22	" " " 6	Joint	.00070		.00010	.00060
"	7	22	" " " 6	Solid plate	.00010	500		
"	6 to 7	22	" after end Hatch No. 6	Joint	.00050		Perceptible	.00050
"	6	22	Nearly abreast main mast	Solid plate	.00018	900	"	.00018
"	5 to 6	22	Abreast main mast	Joint	.00040		"	.00040
"	5	22	Just forward Hatch No. 7	Solid plate	.00012	600		
"	4 to 5	22	Abreast Hatch No. 7	Joint	.00020			
"	4	22	" " " 7	Solid plate	.00004	200		
"	3 to 4	22	Abreast after end Hatch No. 7	Joint	.00040			
B	8	16	Just aft, after bulkhead of superstructure	Solid plate	.00022	1100	0	.00022
D	8 to 9	24	" " " " " "	Joint	More than .00100		.00015	.00085±
Bulwark rail			Two feet aft after " " "	Solid angle	.00045	2250	.00005	.00040
Smooth Sea. After part of ship. Starboard Side.								
C	6 to 7	22	Abreast after end Hatch No. 6	Joint	".00040	800	".00005	".00035
"	6	22	Nearly abreast main mast *	Solid plate	.00012		0	.00013
"	4 to 5	22	Abreast Hatch No. 7	Joint	.00012		.00003	.00009
"	3 to 4	22	Aft, after end of Hatch No. 7		.00015		Perceptible	.00015
"	2	22	Near Bitts *		No strain detected			
Bulwark rail			Two feet aft, after bulkhead of superstructure	Solid angle	.00040	2000		
"			Forward of superstructure	" "	.00055	2750		

* Vertical vibrations in deck very pronounced at these places. In vicinity of main mast very pronounced vertical vibrations, but no strains detected.

To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.





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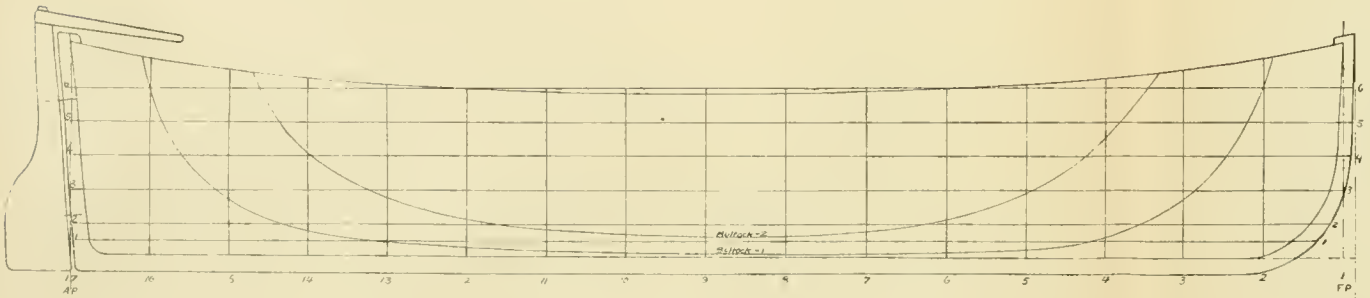

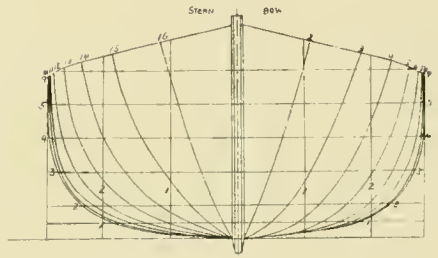

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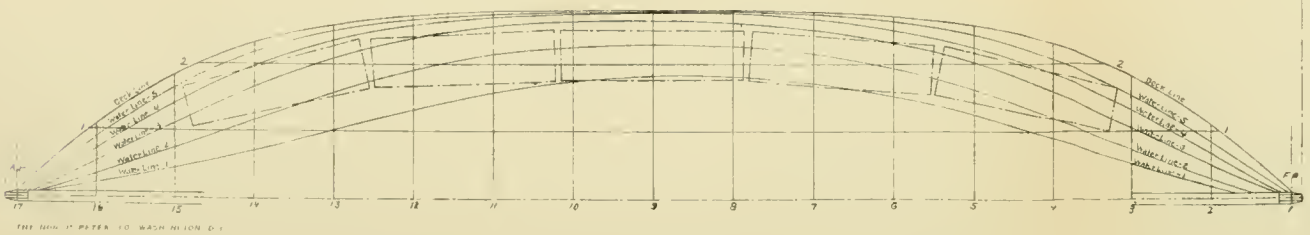

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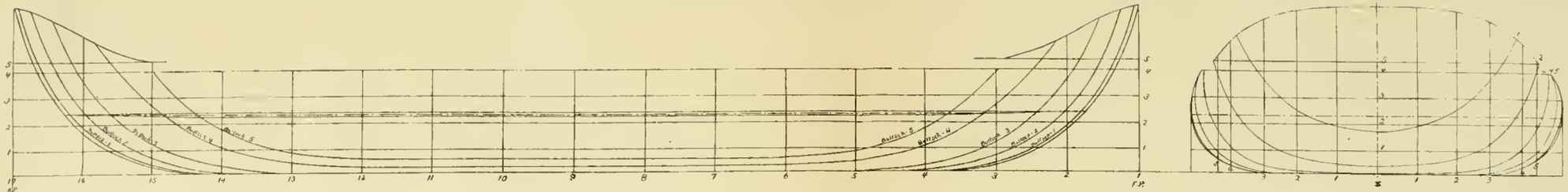
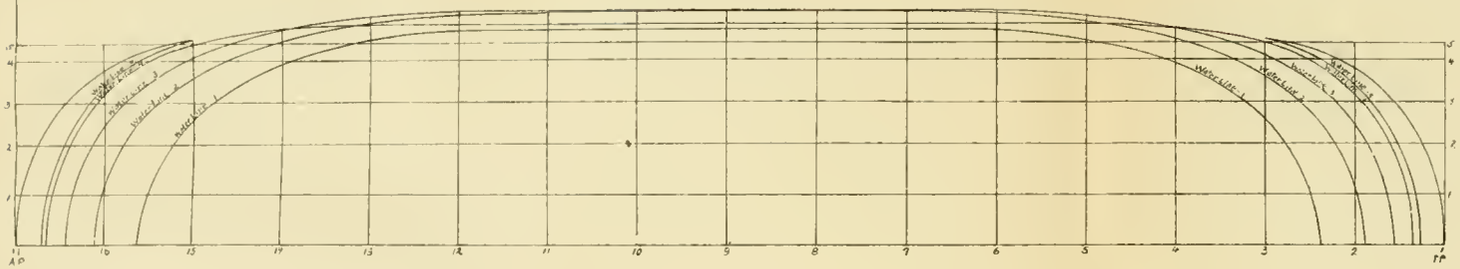
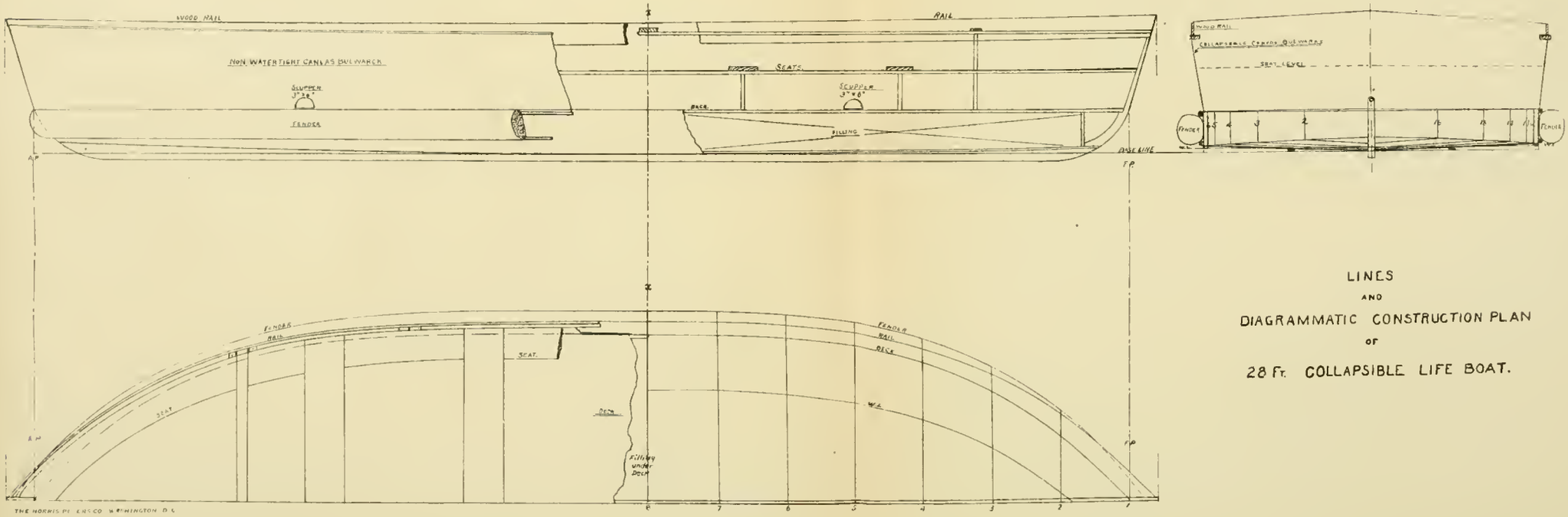




DECKED TYPE 28 FT.
METALLIC

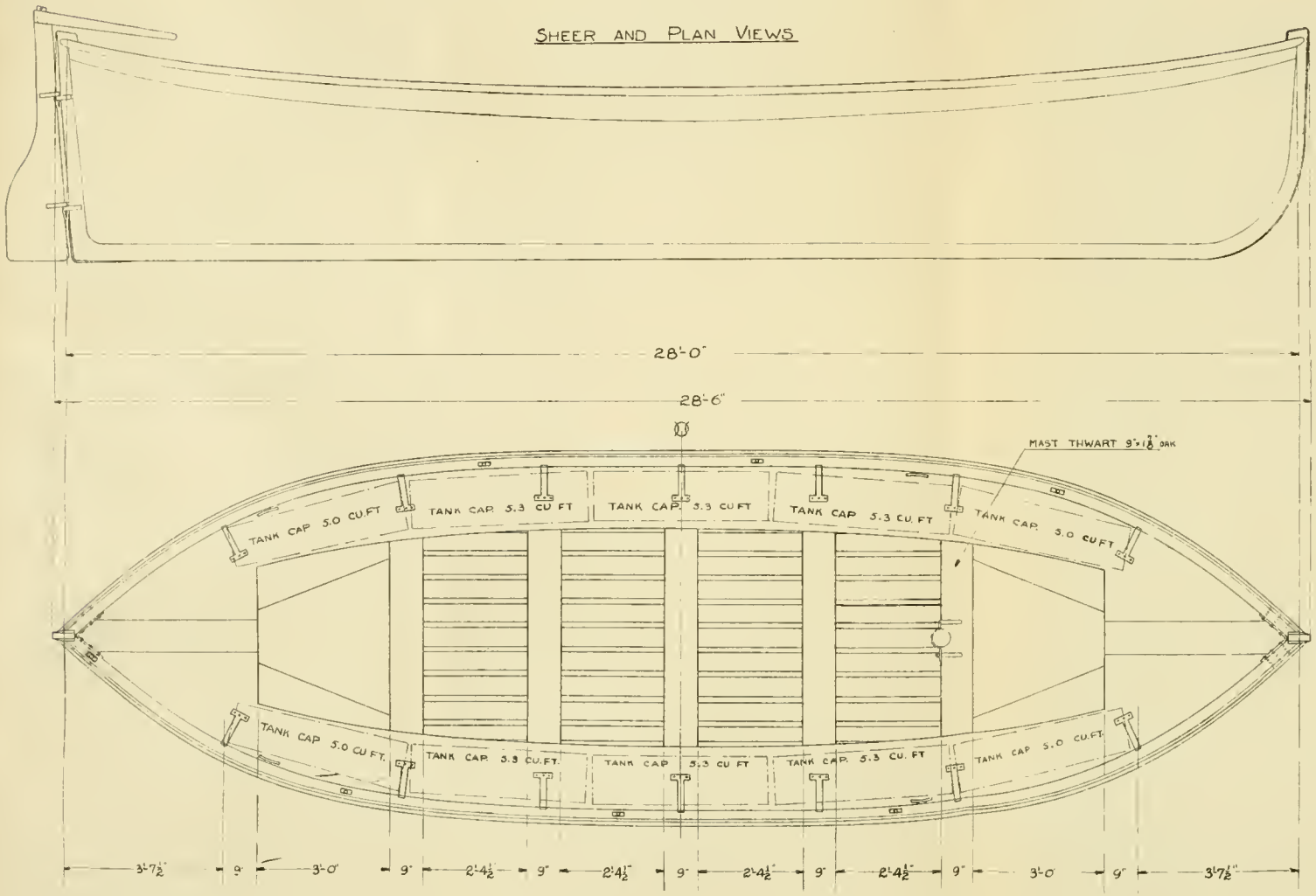


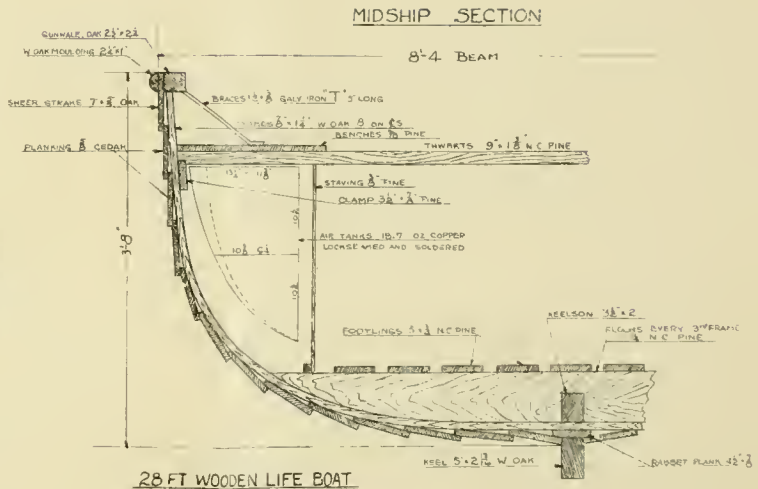
LINES
AND
DIAGRAMMATIC CONSTRUCTION PLAN
OF
28 FT. COLLAPSIBLE LIFE BOAT.

THE HORNIS PRINTING CO. WASHINGTON D.C.

To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.

CONSTRUCTION PLANS OF 28-FT. STANDARD TYPE WOODEN LIFE BOAT.





28 FT WOODEN LIFE BOAT

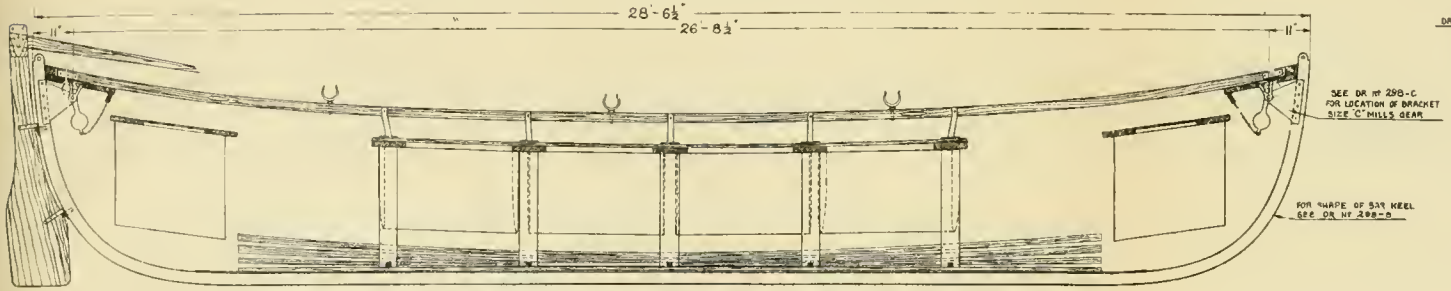
DIMENSIONS

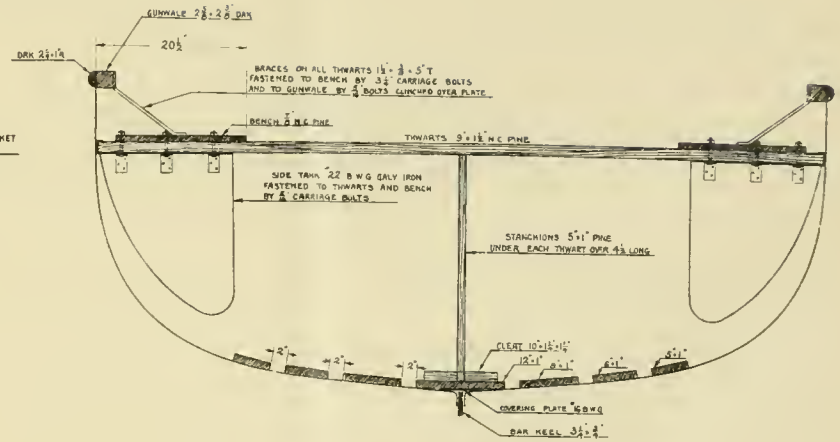
LENGTH MEASURED	28'-0"
BEAM "	8'-4"
DEPTH "	3'-7"
AIR TANK CAPACITY TOTAL	51.8 CU.FT.
CAPACITY	50 PERSONS

THE NORRIS PETERS CO. WASHINGTON, D.C.

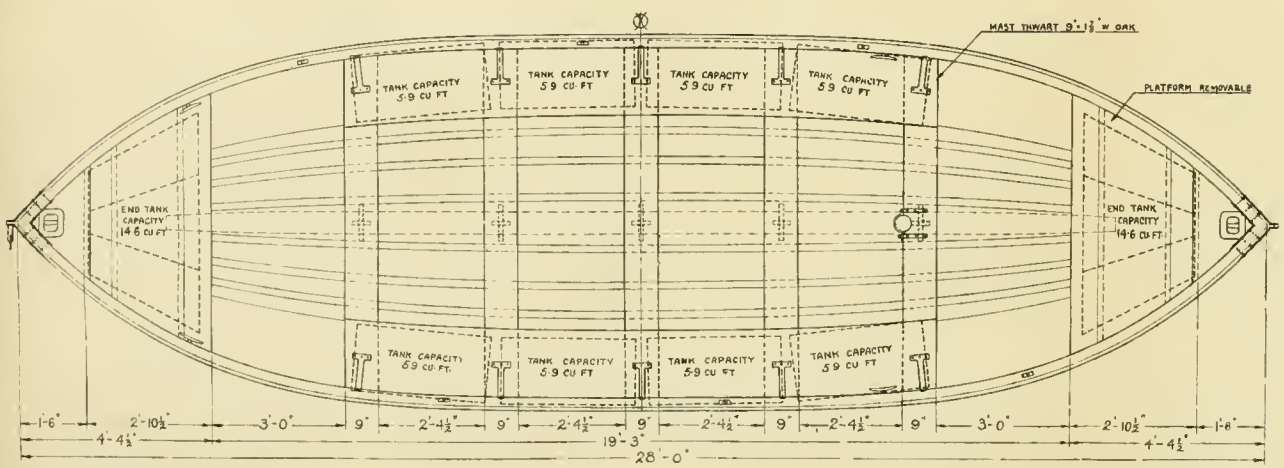
To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.

CONSTRUCTION PLANS OF 28-FT. STANDARD TYPE METALLIC LIFE BOAT.





PLAN VIEW



28 FT METALLIC LIFE BOAT

GENERAL ARRANGEMENT.

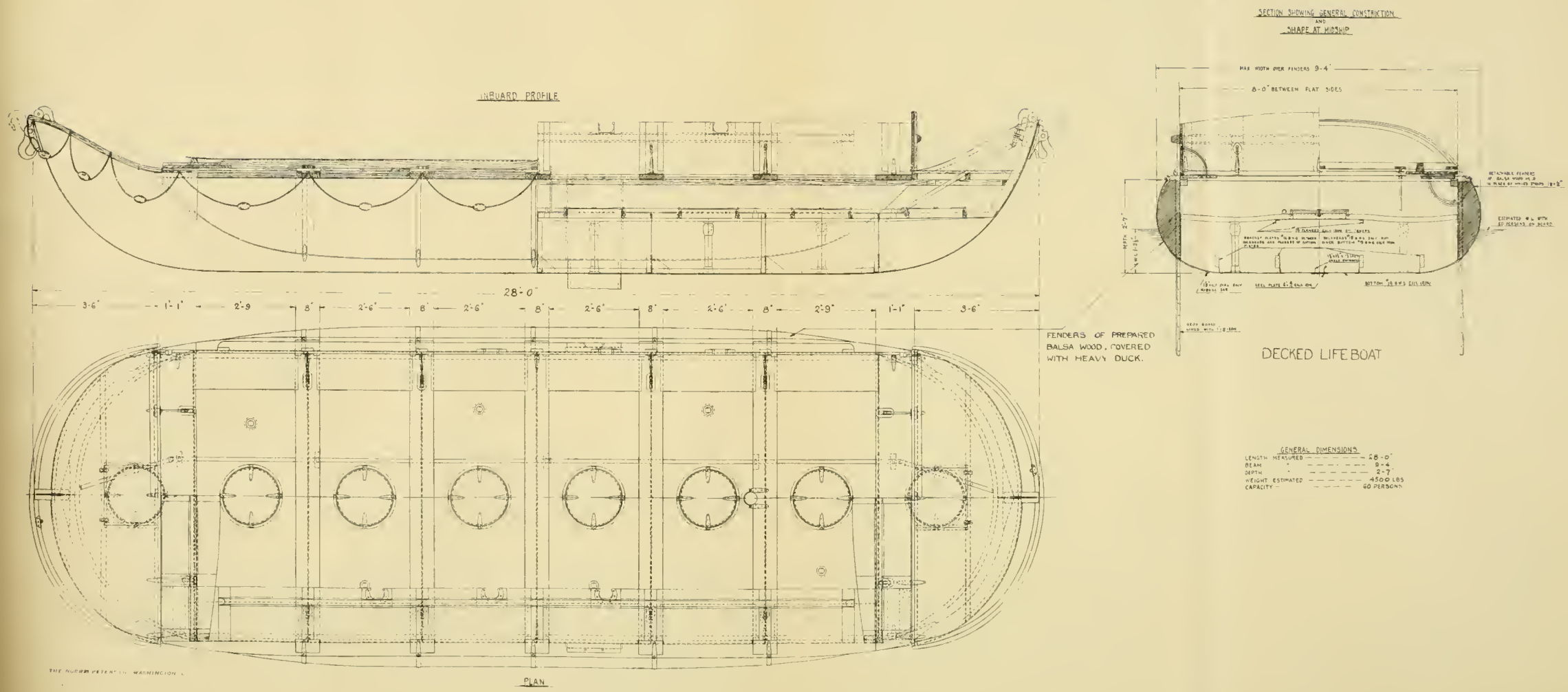
SHOWING CONSTRUCTION OF BOAT AND LOCATION OF INDEPENDENT TANKS.

DIMENSIONS

LENGTH	28'-0"
BEAM	8'-4"
DEPTH	3'-7"
CAPACITY	50 PERSONS
AIR TANK CAPACITY TOTAL	76·4 CU FT

THE NORRIS PETERS CO., WASHINGTON, D. C.

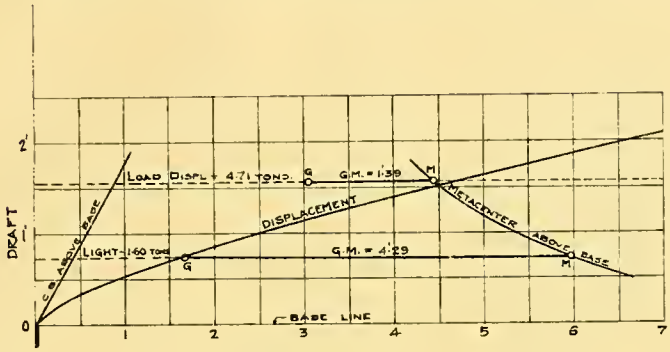
To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.



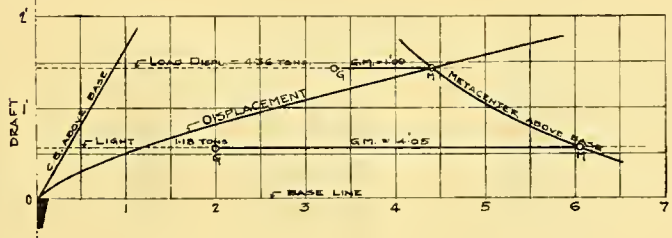
To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.

CURVES OF HULL FUNCTIONS FOR 28-FOOT LIFE BOATS.

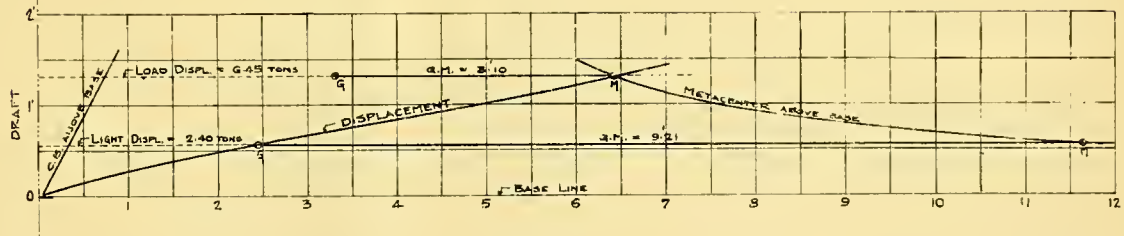
STANDARD, METALLIC



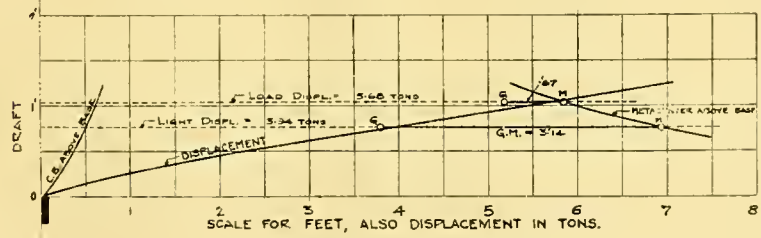
STANDARD, WOODEN



DECKED, METALLIC



COLLAPSIBLE, WOODEN



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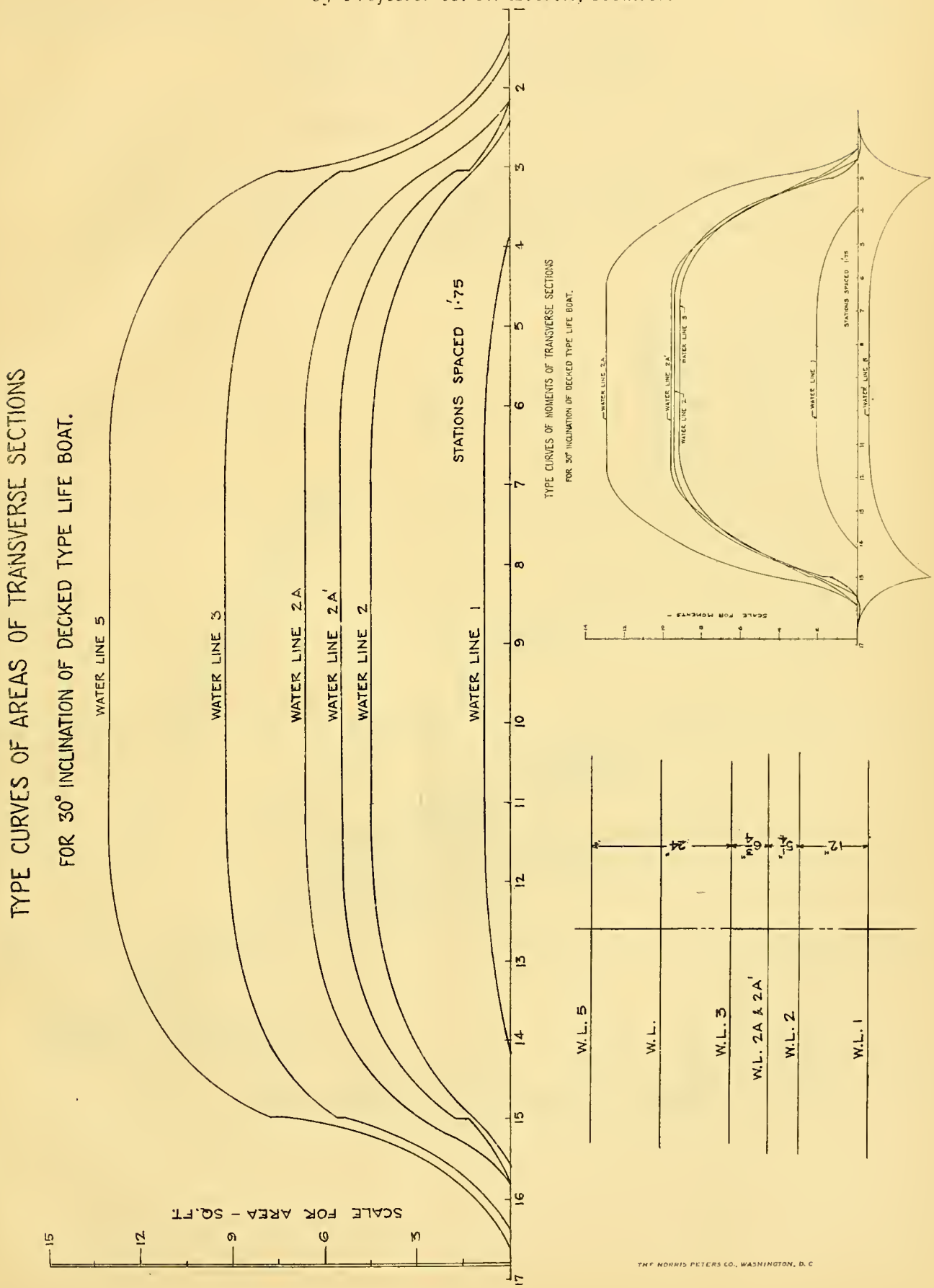
To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.



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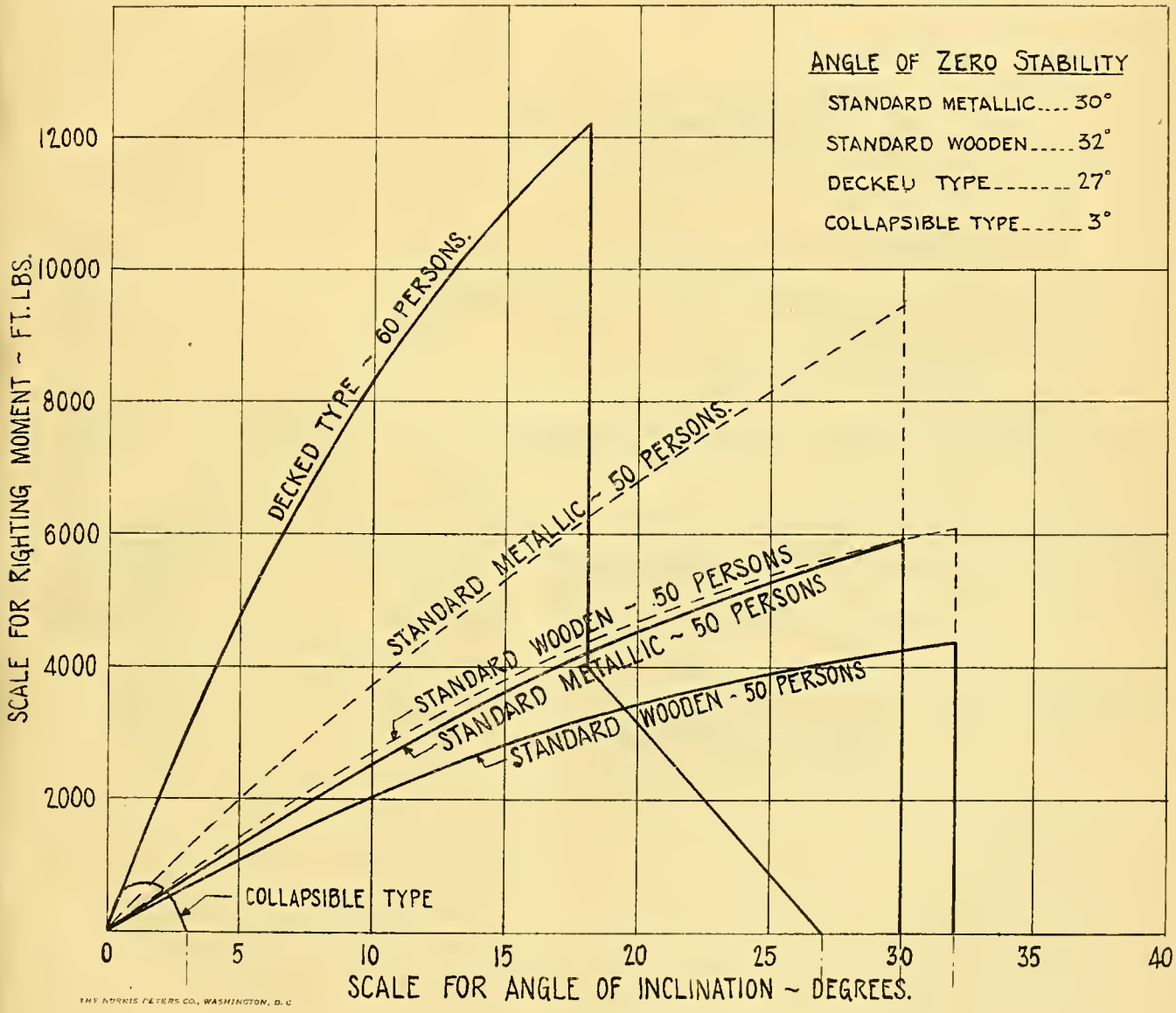
To illustrate paper on "Stability of Lifeboats," by Professor H. A. Everett, Member.

CURVES OF RIGHTING MOMENT OF 28-FT. LIFE BOATS IN LOADED CONDITION.

Full Curves indicate boats loaded to rated capacity with passengers in position designed for them, *i. e.*, on the seats and thwarts.
Dotted Curves indicate same total loading but with part of the load (about 1/3) seated on the bottom of the boat.



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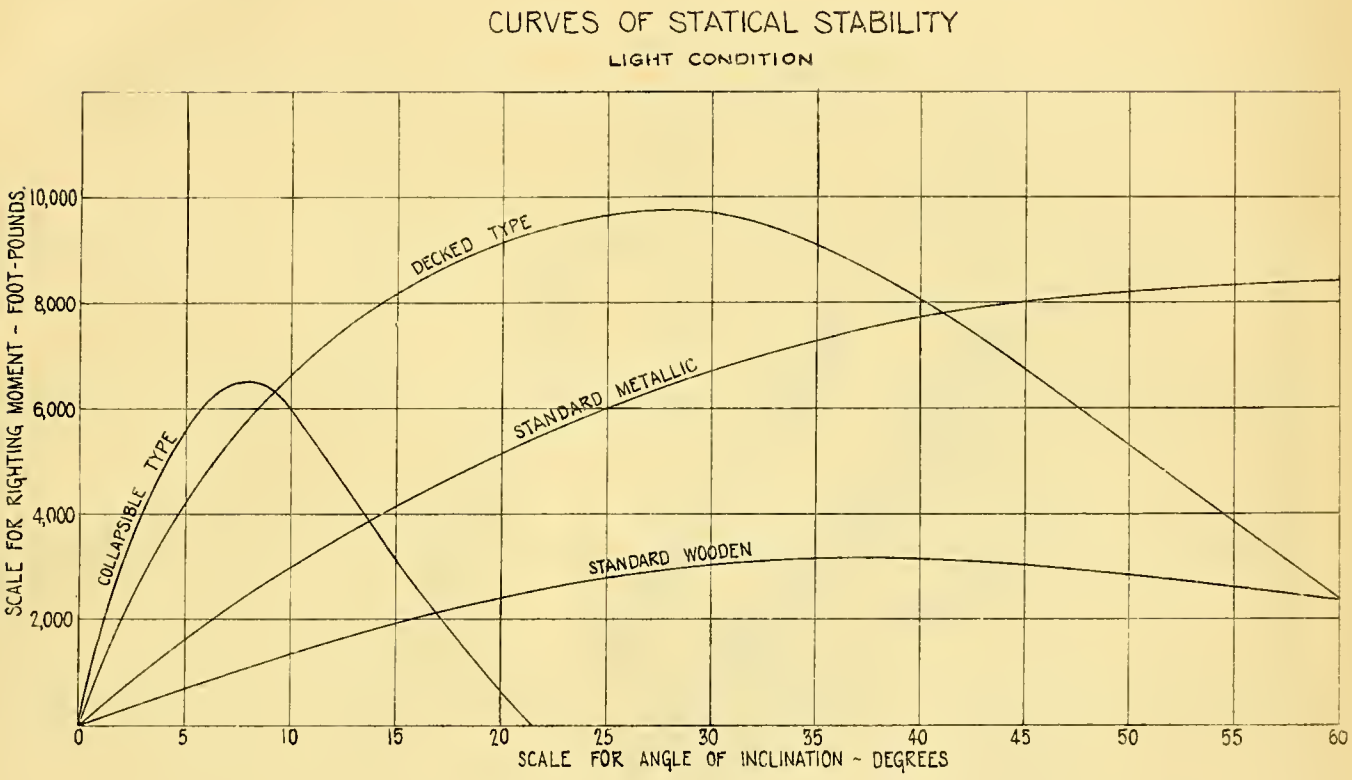

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CURVES OF DYNAMICAL STABILITY 28-FT. LIFE BOATS IN LOADED CONDITION.

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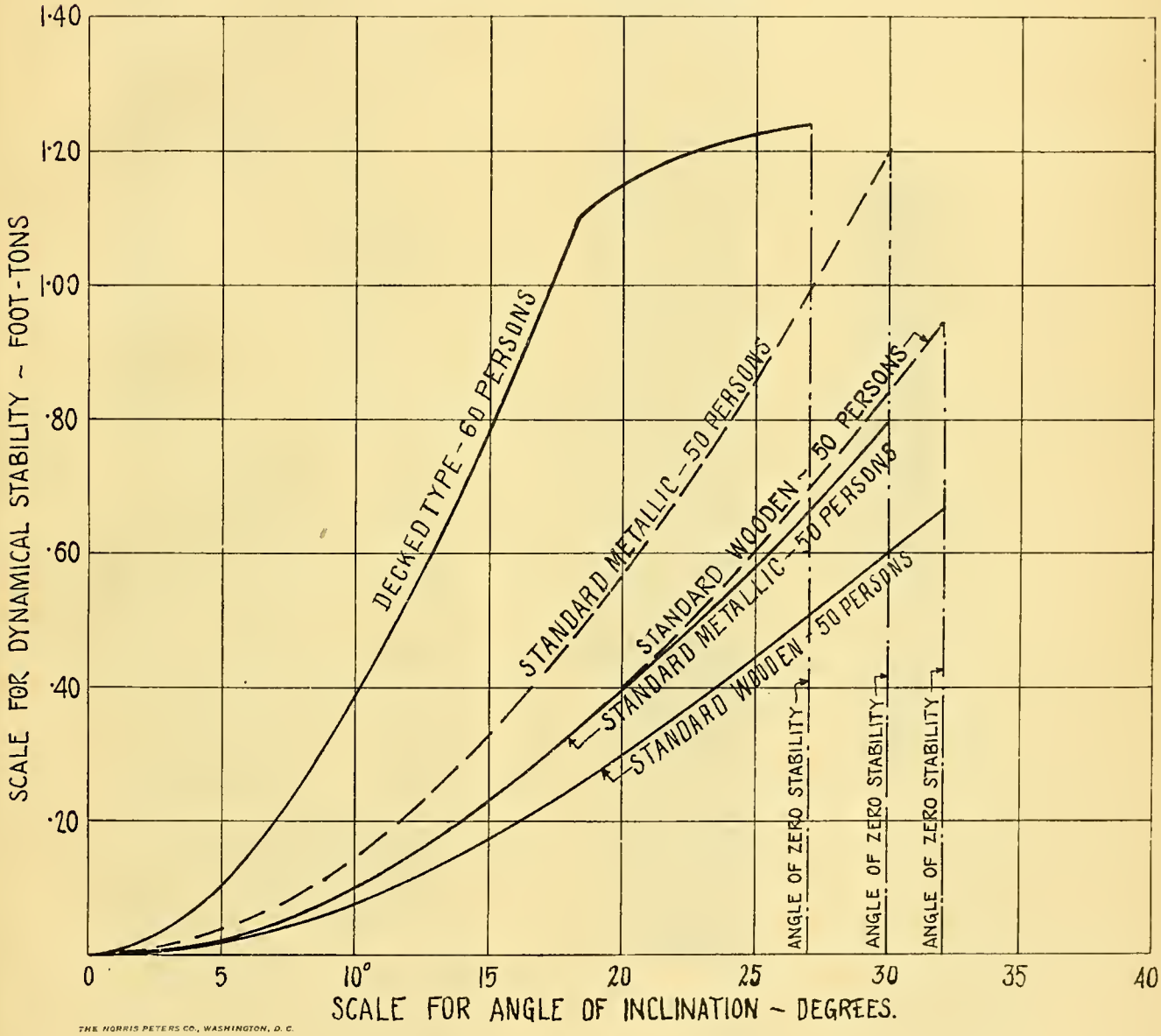

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To illustrate paper on "Change of Shape of Recent Colliers," by Naval Constructor S. F. Smith, U. S. N., Member.

TABLE Nº1 U.S. COLLIER NEPTUNE.
SEE PLATE Nº

CONDITION.	DATE OF READING	TIME	HATCH RESTS. FORD BRIDGE	#1	#2	#3	#4	#5	#6	EXPANSION JOINT OPENINGS. A PORT	A STBD	B PORT	B STBD	C PORT	C STBD	D PORT	D STBD	WEATHER	TEMPERATURE FAHRENHEIT.	DRAFT. FOR'D	AFT	MEAN
BEFORE LAUNCHING	JAN 21, 1911	A.M.	7'-8 3/8"	10'-7 1/2"	11'-4 5/8"	11'-11 1/2"	12'-5 1/4"	12'-9"	12'-9"									CLEAR-WINDY	57° IN SHADE.			
AFTER LAUNCHING	JAN 21, 1911	P.M.	7'-8 3/8"	10'-7 1/2"	11'-4 5/8"	11'-11 1/2"	12'-5 1/4"	12'-9 1/4"	12'-9 1/16"									CLEAR-WINDY	57° "			
	MAR 20, 1911	P.M.	7'-8 3/8"	10'-7 1/2"	11'-4 1/2"	11'-11 1/2"	12'-5 1/4"	12'-9 5/16"	12'-9 1/8"									CLEAR-WINDY	58° "			
	MAY 23, 1911	8.30 A.M.	7'-8 1/8"	10'-6 1/2"	11'-3 1/4"	11'-10"	12'-3 1/2"	12'-7 1/8"	12'-6 7/8"									CLEAR-NO WIND	82° "			
	MAY 23, 1911	2.30 P.M.	7'-7 5/8"	10'-5 7/8"	11'-2 3/8"	11'-8 7/8"	12'-2 1/2"	12'-6 1/4"	12'-6"									CLEAR-WINDY	89° "			
	JUNE 14, 1911	2.00 P.M.								1 1/2"	1 3/4"	1"	1"	1/2"	5/8"	3/8"	1/4"	CLOUDY	73° "			
	JULY 15, 1911	8.30 A.M.								1 5/8"	1 7/8"	1"	1 1/8"	3/4"	3/4"	1/2"	1/4"	PARTLY CLOUDY	73° "	14'-4"	15'-8"	15'-0"
IN DRY DOCK - DOCK DRY.	JULY 20, 1911	9.00 A.M.								1 3/8"	1 3/4"	1"	1"	5/8"	3/4"	3/8"	1/4"	" "	75° IN SHADE.			
" " " - " "	JULY 20, 1911	11.30 A.M.	7'-8 5/8"	10'-7 5/16"	11'-4 3/8"	11'-11 1/4"	12'-5 5/16"	12'-9"	12'-8 1/2"	1 1/2"	1 3/4"	1"	1"	1/2"	5/8"	3/8"	1/4"	" "	97° IN SUN			
LOADED WITH 12488 TONS COAL ALONG SIDE OF COAL PIER WATER IN AFTER PEAK TANKS AND TOP SIDE.	JULY 23, 1911	5.30 A.M.	7'-10 1/4"	10'-9 3/4"	11'-7 1/2"	12'-2 3/4"	12'-9"	13'-0 5/8"	12'-11 1/2"	1 1/2"	1 3/4"	1"	1"	1/2"	5/8"	3/8"	1/4"	CLEAR	65° IN SHADE	28'-8"	29'-9"	29'-2 1/2"

EXTRA BENCH SIGHTS	#7 FEAF LIGHT POOP DK.	#8 ON SKYLIGHT ON POOP DK.	DATE
	3'-9 3/8"	1'-7 5/16"	
	3'-11 11/16"	1'-8 1/16"	7 23-11

TABLE Nº2 U.S. COLLIER ORION.
SEE PLATE Nº

CONDITION.	DATE	TIME	STEM INSTRUMENT	FRONT OF LOWER BRIDGE UNDER COAMING	HATCH REST READINGS. Nº 1	Nº 2	Nº 3	Nº 4	Nº 5	Nº 6	FRONT OF HOUSE TO STEEL POOP PK	1 FOOT AFT OF AFTER COAL TRUNK TO TOP OF STEEL PK HOUSE	WEATHER	TEMPERATURE	DRAFT FOR'D	AFT.	MEAN
BEFORE LAUNCHING.	MAR. 23, 1912	10.30 A.M.	28 5/16"	2 15/16"	10'-1 1/2"	10'-9 1/2"	11'-7 1/2"	12'-2 3/8"	12'-5 3/4"	12'-6 1/2"	12'-3"	3'-8 3/4"	FAIR	35° F			
AFTER LAUNCHING.	" - -	12.40 P.M.	28 5/16"	3 1/4"	10'-1	10'-9 5/8"	11'-6 3/8"	12'-1 1/2"	12'-5"	12'-5 1/2"	12'-2 1/8"	3'-8 3/8"	"	40° F	4'-2"	10'-7"	7'-4 1/2"
ALL MACHINERY & WINCHES ON BOARD.	MAY 22, 1912	3.00 P.M.	28 5/16"	3 9/16"	10'-0 5/8"	10'-9 5/8"	11'-5 3/8"	12'-0 1/2"	12'-4"	12'-4 1/2"	12'-1"	3'-7 3/4"	"	76° F	5'-1"	17'-2"	11'-1 1/2"
BEFORE GOING IN DRY DOCK.	JUNE 28, 1912	1.30 P.M.	28 5/16"	4 1/8"	9'-11 7/8"	10'-7 1/16"	11'-4 3/8"	11'-11"	12'-2 1/2"	12'-3 3/4"	12'-1 1/16"	3'-7 15/16"	CLEAR	77° F	14'-0"	16'-2"	15'-1"
IN DRY DOCK - DOCK DRY	" 29, 1912	11.30 A.M.	28 5/16"	3 3/8"	10'-1"	10'-8 1/2"	11'-6 1/2"	12'-1 1/2"	12'-4 3/8"	12'-5 3/8"	12'-2 1/2"	3'-8 3/4"	"	90° F			
LOADED 12500 TONS COAL 10498 CARGO 1802 BUNKER.	JULY 5, 1912	10.40 A.M.	28 5/16"	2 1/2"	10'-1 1/4"	10'-8 15/16"	11'-6 3/8"	12'-1 1/4"	12'-4"	12'-3 15/16"	12'-0 1/8"	3'-7 3/8"	"	84° F	25'-3	30'-3	27'-9

TANK TOP READINGS

CONDITION.	DATE	TIME	BULKHEAD Nº 45	BULKHEAD Nº 53	BULKHEAD Nº 61	BULKHEAD Nº 69	BULKHEAD Nº 77	BULKHEAD Nº 85	INSTRUMENT BULKHEAD Nº 91
BEFORE LAUNCHING	MAR. 23, 1912	10 A.M.	36 13/16"	36 11/16"	36 9/16"	36 11/16"	36 5/16"	36 5/16"	36 13/16"
AFTER LAUNCHING.	" " -	12.40 P.M.	36 15/16"	36 1/16"	36"	35 3/8"	35 7/8"	36 7/16"	36 15/16"
MACHINERY INSTALLED.	JUNE 5, 1912	3.05 P.M.	36 15/16"	36 7/16"	35 15/16"	36 3/8"	36 3/8"	36 1/2"	36 15/16"

To illustrate paper on "Change of Shape of Recent Colliers," by Naval Constructor S. F. Smith, U. S. N., Member.

TABLE Nº 3 U.S. COLLIER JASON

SEE PLATE Nº

CONDITION	DATE	TIME	STEM INSTRUMENT	FRONT OF LOWER BRIDGE UNDER COAMING	HATCH REST READINGS. Nº 1	Nº 2	Nº 3	Nº 4	Nº 5	Nº 6	TOP OF POOP DECK HOUSE FORD. END.	TOP OF AFTER SIDE OF COAL TRUNK ON POOP DECK HOUSE	WEATHER.	TEMPERATURE.	DRAFT. FOR'D	AFT.	MEAN.
BEFORE LAUNCHING	NOV. 15, 1912	10.30 A.M.	26"	4 1/2"	10'-0 1/8"	10'-9 3/4"	11'-5 7/8"	12'-1 8"	12'-4 13/16"	12'-5 3/16"	4'-2 5/8"	2'-2 5/8"	CLOUDY	46° F			
AFTER LAUNCHING	NOV. 16, 1912	1.30 P.M.	26"	4 7/16"	10'-0"	10'-9 9/16"	11'-5 9/16"	12'-0 3/4"	12'-4 1/2"	12'-5"	4'-2 1/2"	2'-2 9/16"	FAIR.	49° F	4'-9	11'-6"	8'-1 1/2"
SHIP COMPLETED	FEB. 21, 1913	3.30 P.M.	26"	5 3/8"	9'-10 13/16"	10'-9 11/16"	11'-3 1/4"	11'-10 3/8"	12'-2 5/8"	12'-3 1/8"	4'-2 1/16"	2'-2 7/16"	CLEAR	60° F	9'-11"	18'-3"	14'-1"
ON BLOCKS IN DRY DOCK.	FEB. 24, 1913	3.00 P.M.	26"	4 1/2"	10'-0 1/8"	10'-9 11/16"	11'-5 11/16"	12'-0 3/4"	12'-4 9/16"	12'-5 1/16"	4'-2 9/16"	2'-2 9/16"	FAIR	34° F			
LOADED 12338 TONS CARGO COAL 2116 TONS BUNKER COAL, & 385 TONS OF WATER.	MAR. 12, 1913	2.45 P.M.	26"	3 15/16"	10'-1 3/8"	10'-11 3/16"	11'-7 3/4"	12'-3 1/4"	12'-6 15/16"	12'-7 1/8"	4'-4 5/16"	2'-3 5/8"	CLEAR	49° F	25'-8"	29'-4"	27'-6"
UNLOADED	APR. 3, 1913	4.00 P.M.	26"	5 15/16"	9'-10"	10'-6 1/2"	11'-1 13/16"	11'-8 5/8"	12'-0 3/4"	12'-1 1/2"	3'-11 7/16"	2'-0 1/8"	CLEAR	75° F	10'-10"	16'-10"	13'-10"
REPAIRS COMPLETED	JUNE 3, 1913	10.30 A.M.	26"	5 1/16"	9'-11 7/16"	10'-8 5/8"	11'-4 5/16"	11'-11 1/4"	12'-2 7/8"	12'-3 3/8"	4'-1 3/16"	2'-1 13/16"	FAIR	75° F	3'-0"	21'-6"	12'-3"
ON BLOCKS IN DRY DOCK REPAIRS COMPLETED	" 10, 1913	10.30 A.M.	26"	4 1/2"	10'-0 1/8"	10'-9 7/8"	11'-5 9/8"	12'-0 3/4"	12'-4 5/16"	12'-4 11/16"	4'-2 1/4"	2'-2 7/16"	FAIR	64° F			
LOADED 10478 TONS CARGO COAL, 2167 TONS BUNKER COAL & 459 TONS OF WATER	" 14, 1913	4.15 P.M.	26"	3 5/8"	10'-1 5/16"	10'-11 7/16"	11'-7 7/8"	12'-3 3/16"	12'-6 13/16"	12'-6 15/16"	4'-3 15/16"	2'-3 3/16"	FAIR	92° F	26'-2"	30'-8"	28'-2 1/2"

TANK TOP READINGS.

CONDITION.	DATE	TIME	BULKHEAD No 45	BULKHEAD No 53	BULKHEAD No 61	BULKHEAD No 69	BULKHEAD No 77	BULKHEAD No 85	BULKHEAD No 91
BEFORE LAUNCHING	NOV. 15, 1912	10.45 A.M.	37 15/16"	39 5/16"	39 3/16"	39"	38 1/2"	38 1/4"	37 15/16"
AFTER LAUNCHING.	NOV. 16, 1912	1.45 P.M.	37 15/16"	37 3/4"	37 1/2"	37 3/8"	37 11/16"	38 1/8"	37 15/16"

TABLE Nº 4 U.S. COLLIER NEREUS.

SEE PLATE Nº

ACTUAL READINGS.

DATE	JULY 31, 1913	AUGUST 1, 1913	AUGUST 14, 1913	AUGUST 14, 1913	AUGUST 28, 1913
CONDITION	Nº 1	Nº 2	Nº 3	Nº 4	Nº 5
STATIONS	(ALL OBSERVATIONS WERE READ AS SAG FROM CONDITION Nº1)				
A	0	2 5/8"	2 1/2"	1 1/8"	4 5/16"
B	0	3 7/8"	3 1/2"	1 1/2"	6"
C	0	3 3/8"	3 1/16"	1 3/8"	5 3/8"
D	0	1 5/8"	1 1/2"	5/8"	2 3/8"
E	0	0	0	0	0

CONDITION Nº1 FIVE FEET OF WATER IN TOPSIDE TANK Nº2 STARBOARD; TOPSIDE TANKS Nº3 PORT & STAR'B. FULL OF WATER; OIL CARGO TANKS Nº1 STAR'B & Nº4 PORT FULL OF WATER. VESSEL PRACTICALLY COMPLETE, AND LIGHT EXCEPT FOR WATER.
CONDITION Nº2 SAME AS Nº1 EXCEPT THAT VESSEL WAS IN DOCK, DOCK DRY.
CONDITION Nº3 VESSEL IN DOCK, DOCK DRY; VESSEL COMPLETED AND LIGHT TOP SIDE TANKS Nºs 1 & 2 STAR'B. PORT, FULL OF WATER.
CONDITION Nº4 SAME AS Nº3 BUT VESSEL FLOATING IN DRY DOCK.
CONDITION Nº5 VESSEL COMPLETED AND LOADED WITH ABOUT 12,500 TONS OF COAL.

CORRECTED READINGS

DATE	JULY 31, 1913	AUGUST 23, 1913	AUGUST 28, 1913
CONDITION	Nº 1	Nº 2	Nº 3
STATIONS	HOG.	HOG.	SAG.
F.P.	0	0	0
AXIS OF LEVEL	1 1/2"	7/8"	1 3/8"
A	3 5/16"	1 3/4"	2 7/8"
B	4 1/4"	2 5/16"	3 3/16"
C	3 13/16"	2 1/16"	2 3/8"
D	2 1/8"	1 1/8"	1 3/4"
E	1/2"	5/16"	7/16"
A.P.	0	0	0

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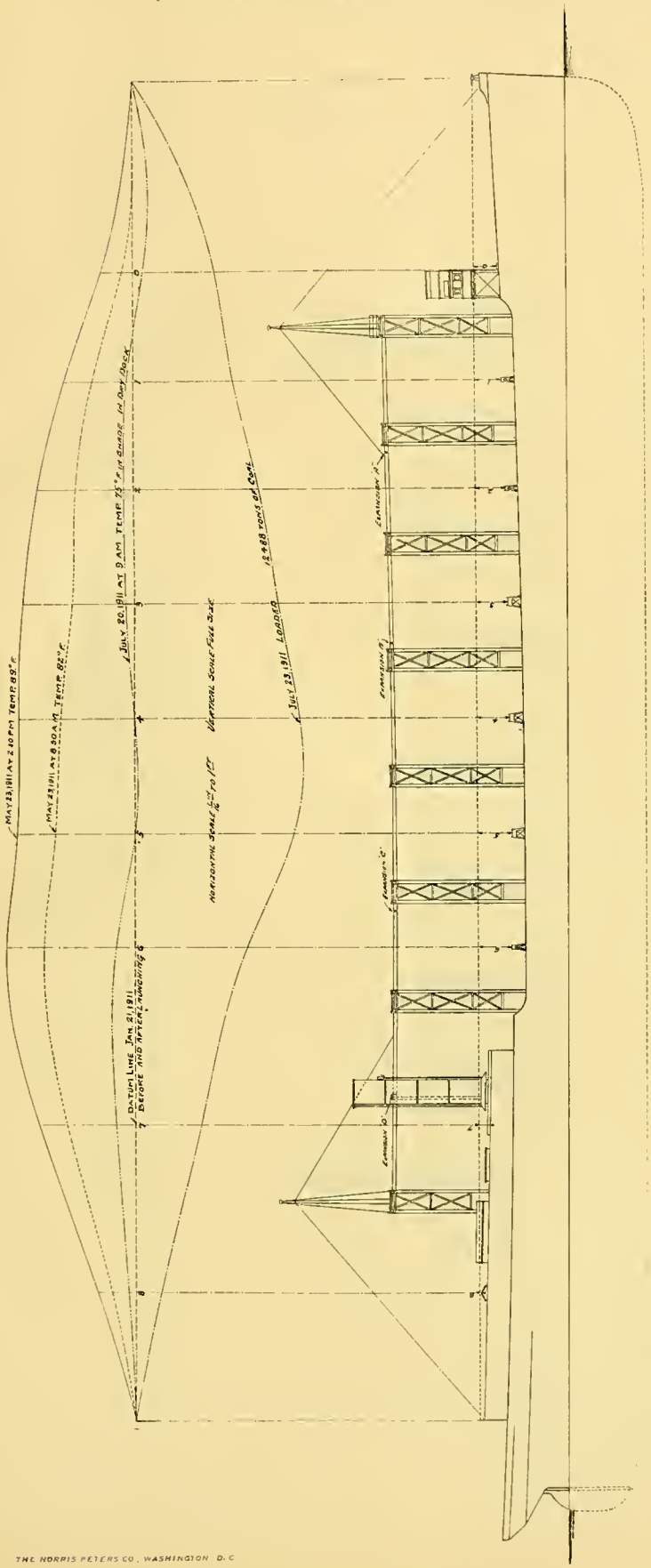
To illustrate paper on "Change of Shape of Recent Colliers."
by Naval Constructor S. F. Smith, U. S. N., Member.

U.S.S. NEPTUNE



U.S. COLLIER NEPTUNE.
CURVES SHOWING HOGGING & SAGGING

EXPANSION JOINTS DESIGNED TO ALLOW ONE INCH EXPANSION AND ONE INCH CONTRACTION WHEN SET WITH ONE INCH OPENING

DATE RECORDED	TIME	EXPANSION JOINT OPENINGS A	B	C	D	WEATHER	TEMPERATURE
		Port Stbd	Port Stbd	Port Stbd	Port Stbd		
June 14, 1911	2.00 P.M.	1/2 1 1/4	1" 1"	1/2 1/2	1/4 1/4	CLOUDY	73° FAHR.
July 5, 1911	8.30 A.M.	1/8 1/8	1/8 1"	1/16 1/16	1/4 1/4	PARTLY CLOUDY	73° "
July 20, 1911	9.00 A.M.	1/4 1/4	1" 1"	1/16 1/16	1/4 1/4	"	75° "
July 20, 1911	11.30 P.M.	1/8 1/8	1" 1"	1/16 1/16	1/8 1/8	CLEAR	97° "
July 23, 1911	2.00 P.M.	1/4 1/4	1" 1"	1/16 1/16	1/4 1/4	CLEAR	65° "

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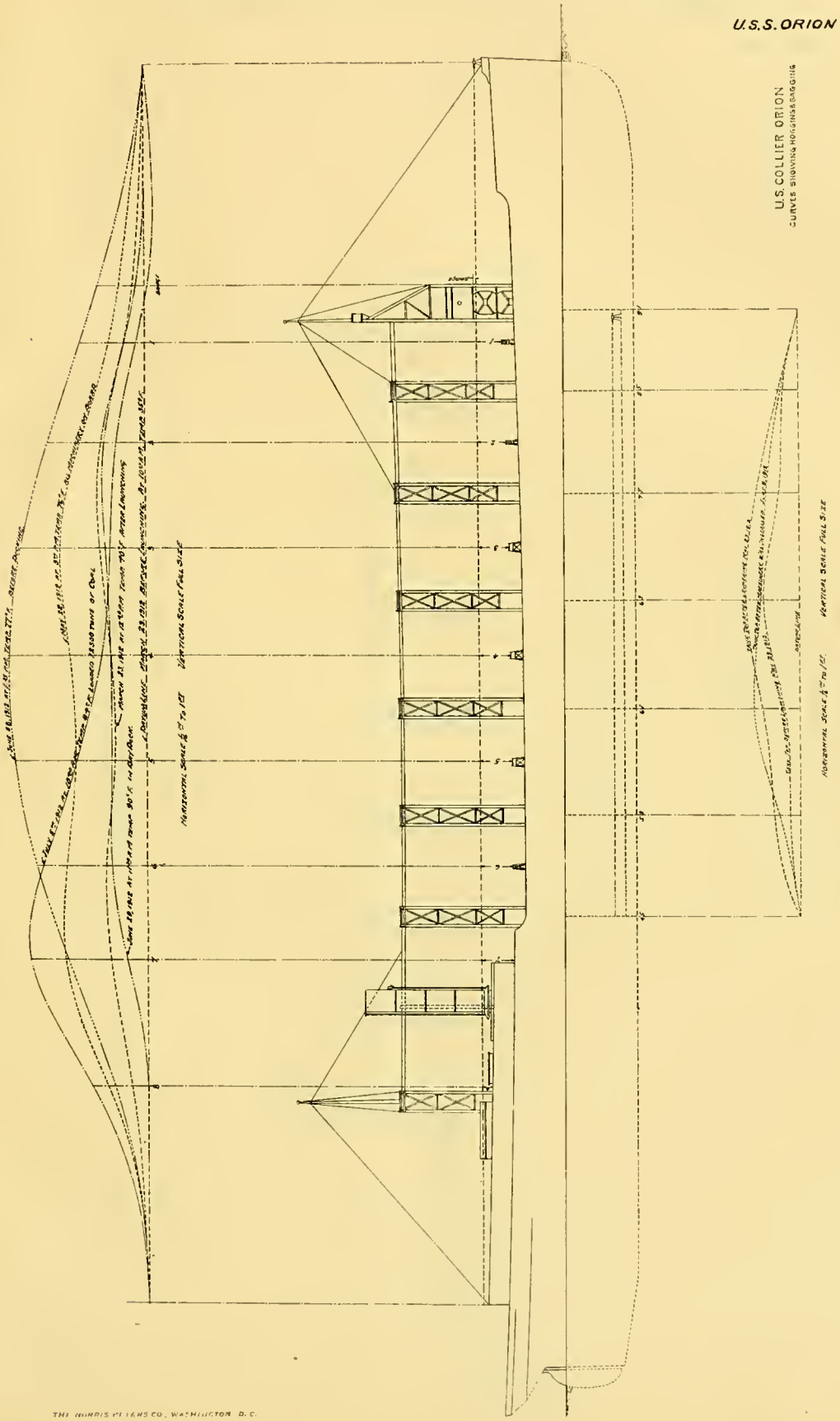

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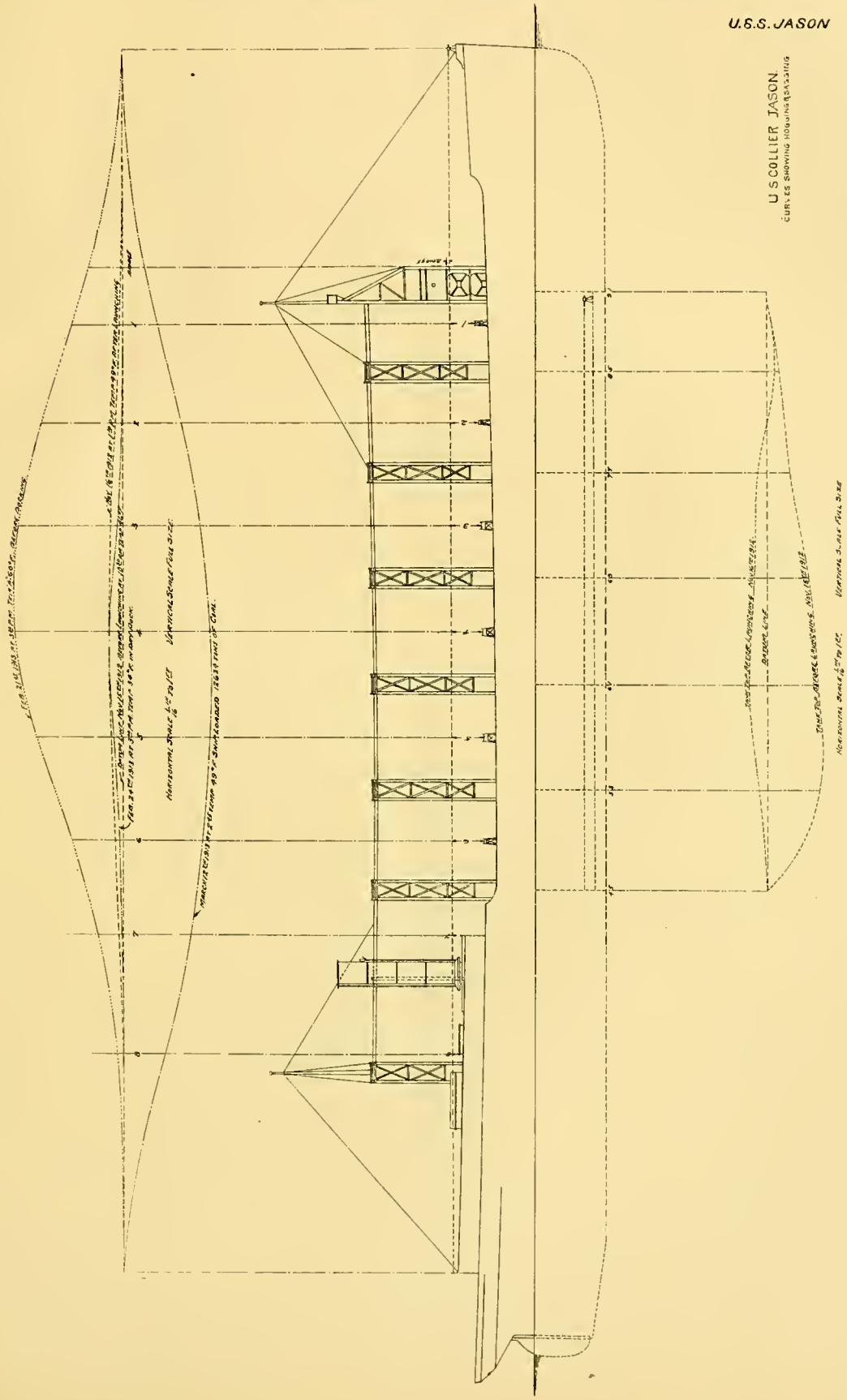

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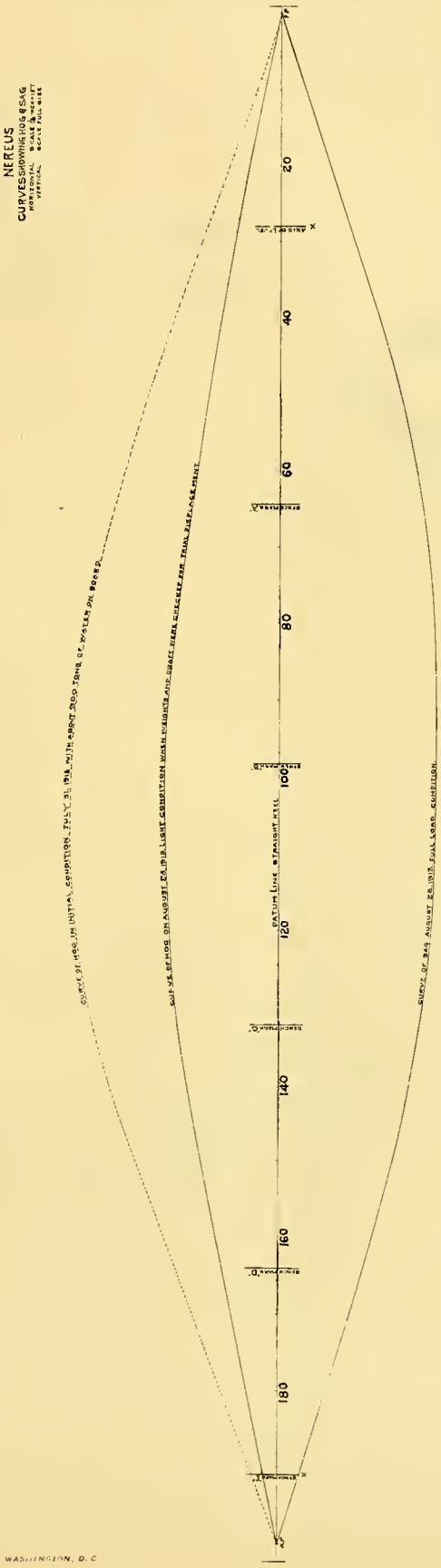

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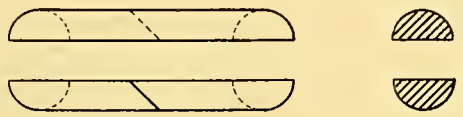

FIG 1

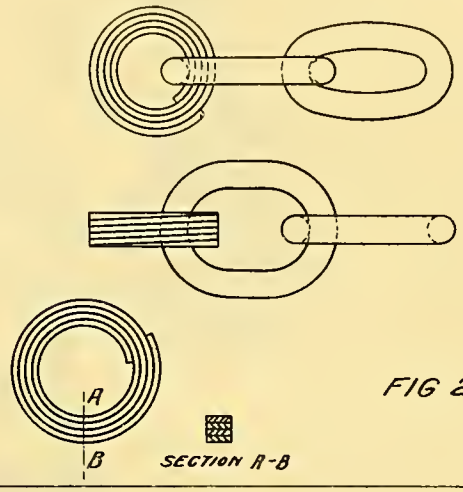

FIG 2

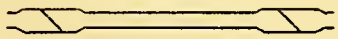

FIG 3

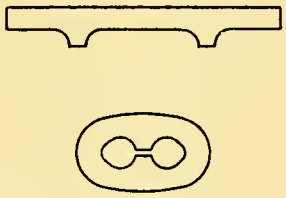

FIG 4

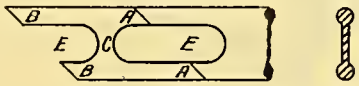

FIG 5

FIG 6

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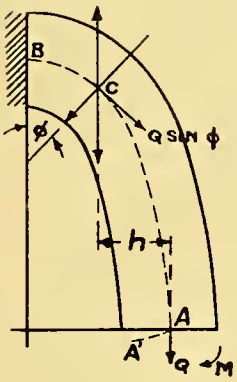

FIG 7

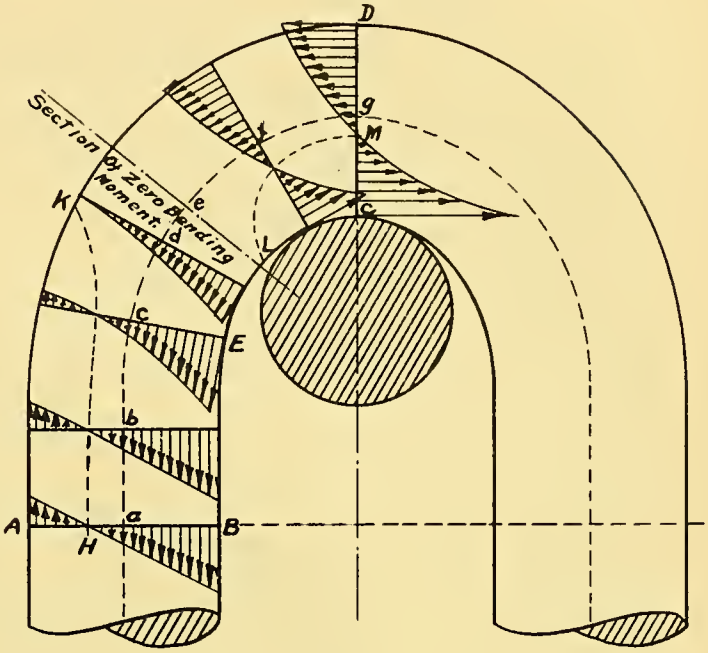

FIG 8

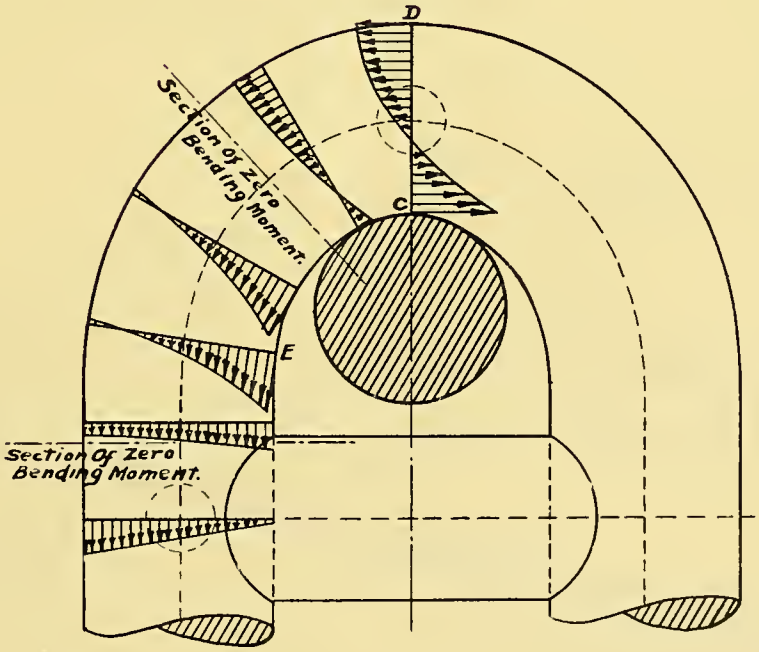

FIG 9

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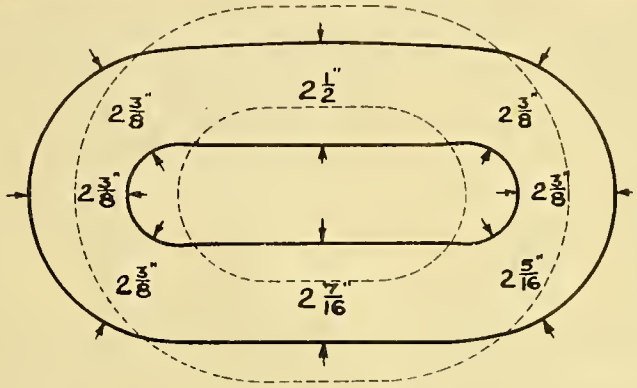

FIG 10

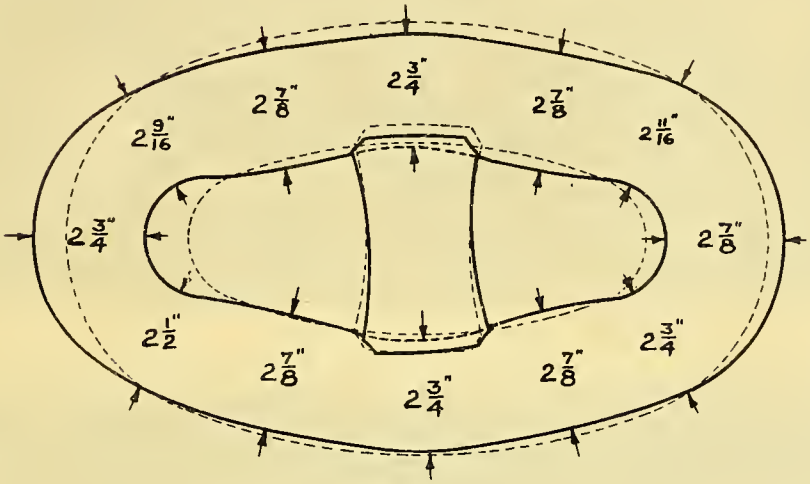

FIG 11

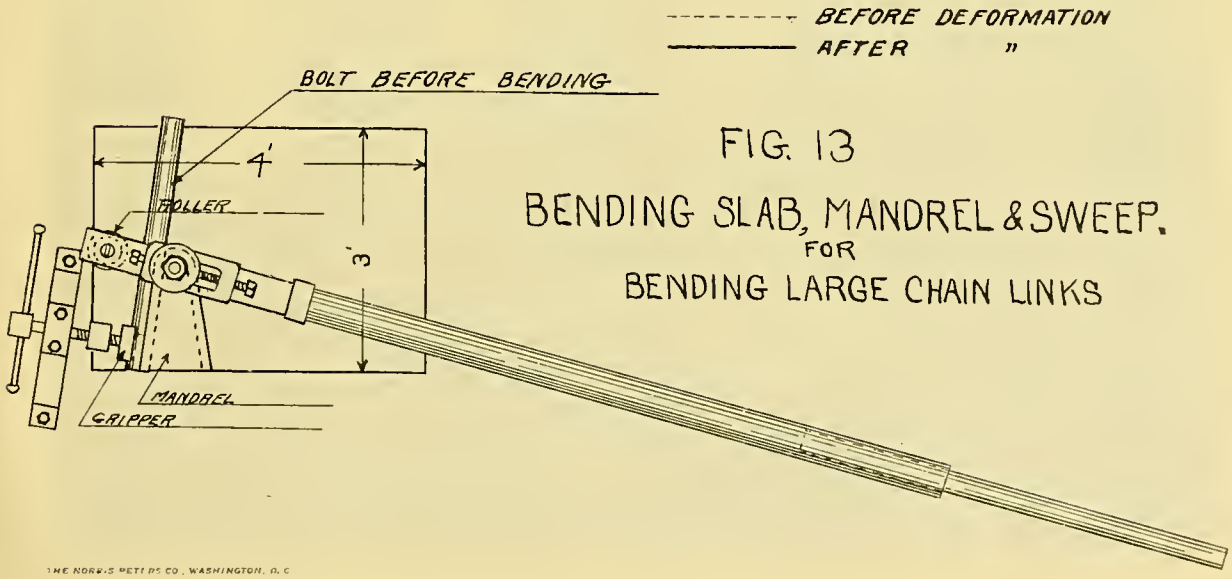

FIG. 13

BENDING SLAB, MANDREL & SWEEP.
FOR
BENDING LARGE CHAIN LINKS

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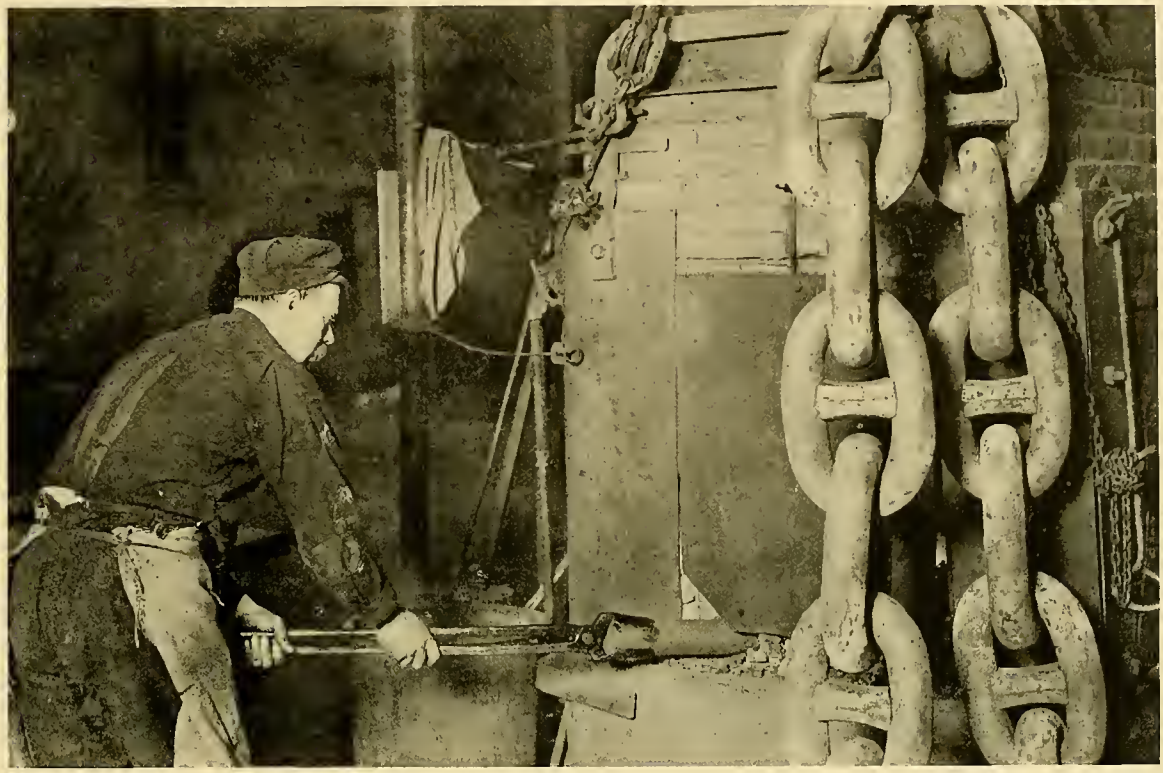

Fig. 12.—Present Method of Heating Bolt.

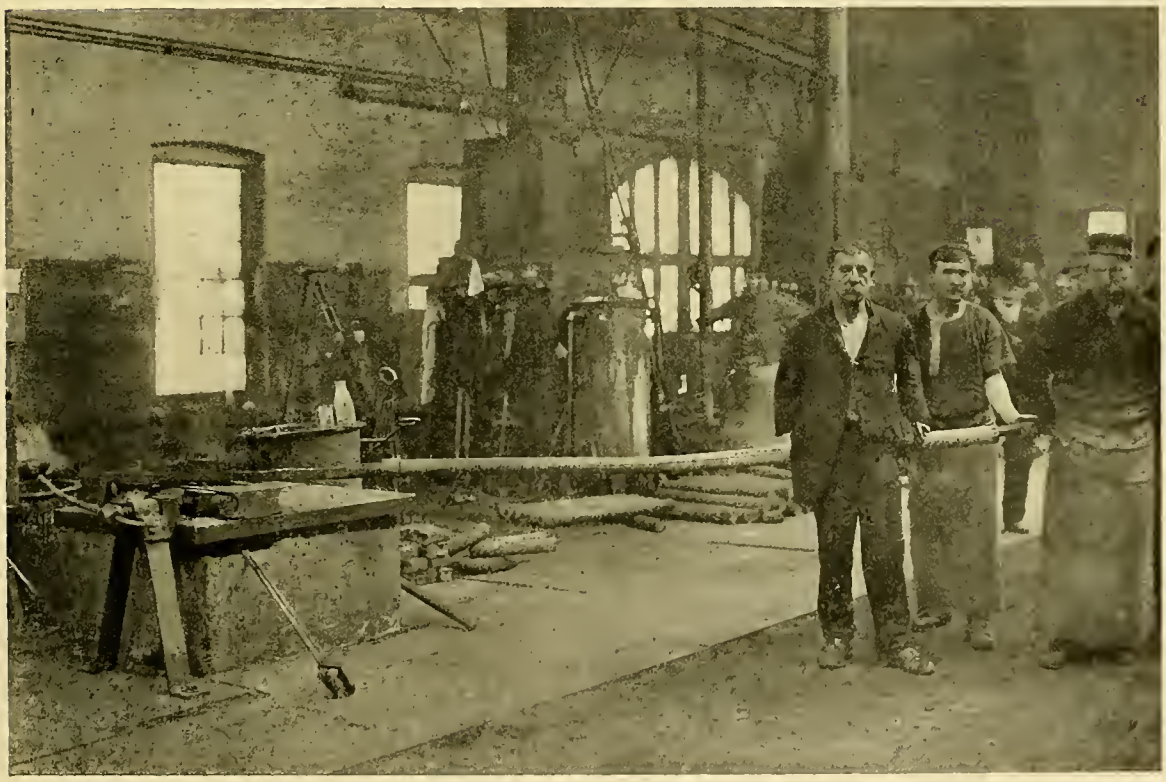

Fig. 14.—Method of Bending Bolt. Ready to Bend.

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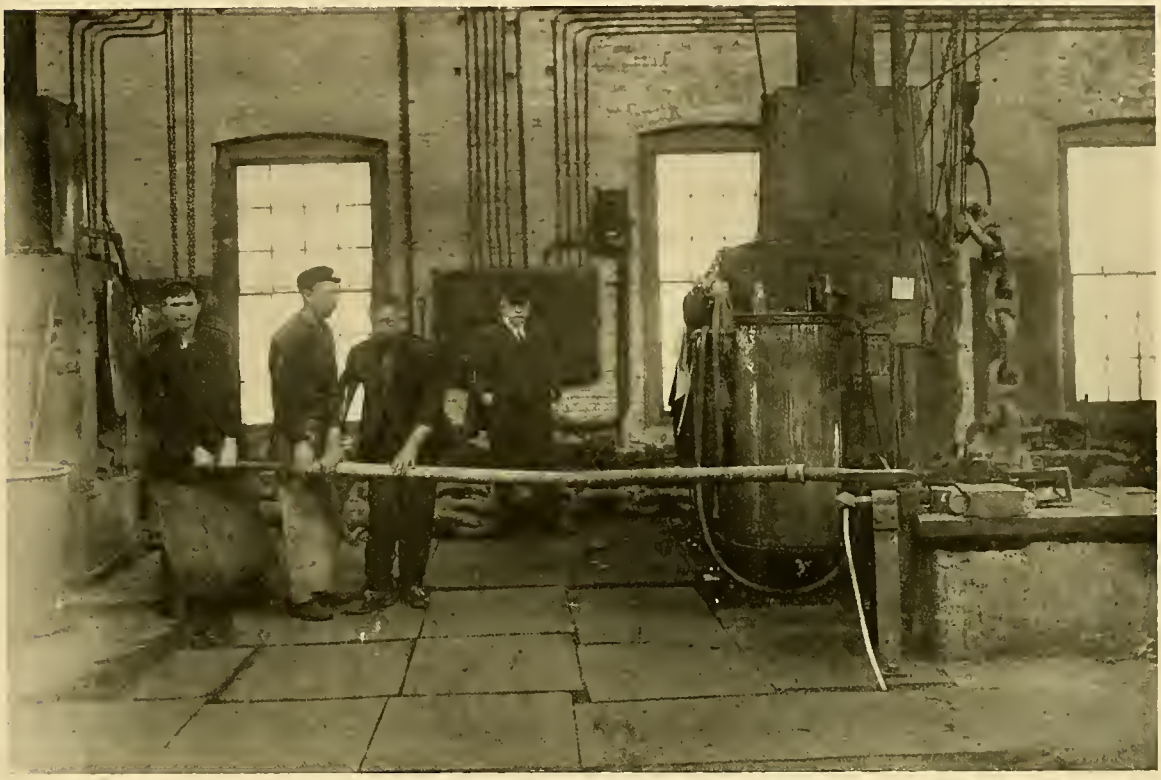

Fig. 14A.—Method of Bending Bolt. Bolt Bent.

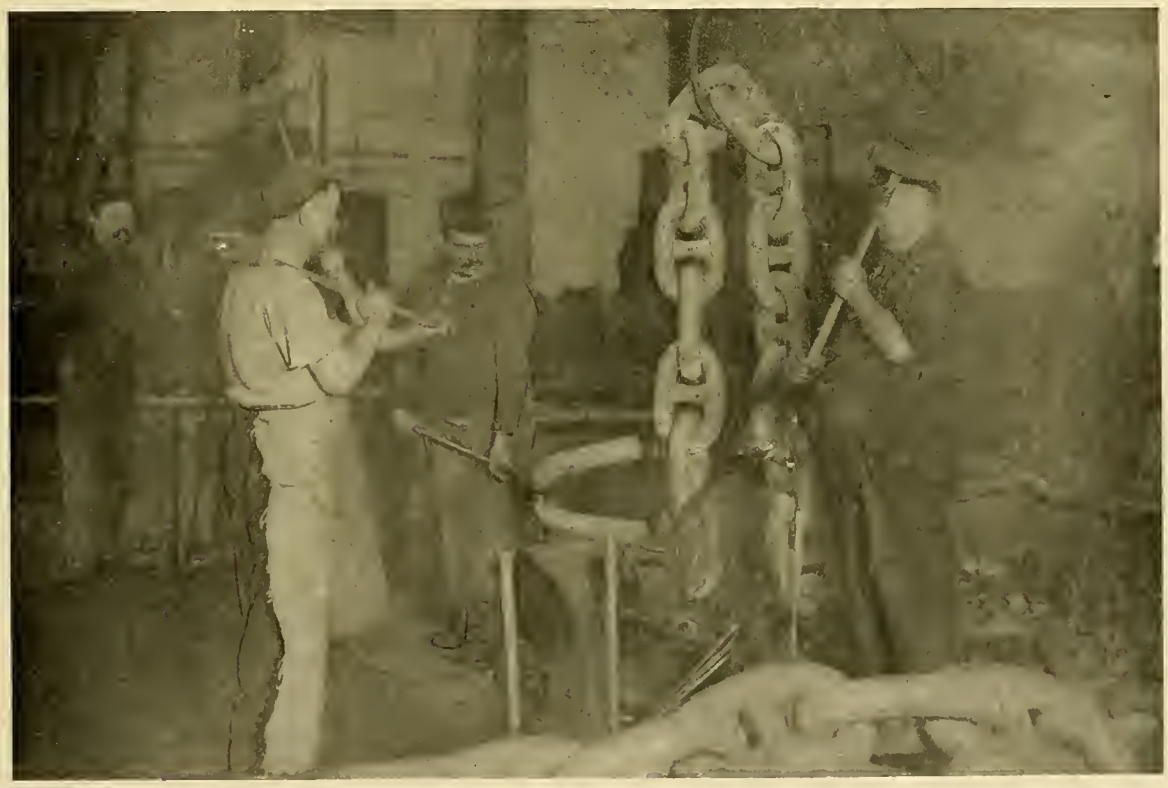

Fig. 15.—Closing in Bent Bolt.

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Fig. 15A.—Throwing in the Ends Preparatory to Scarfing.

Fig. 16.—Scarf as Made at Present.

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Fig. 16A.—Present Method of Making Scarf.

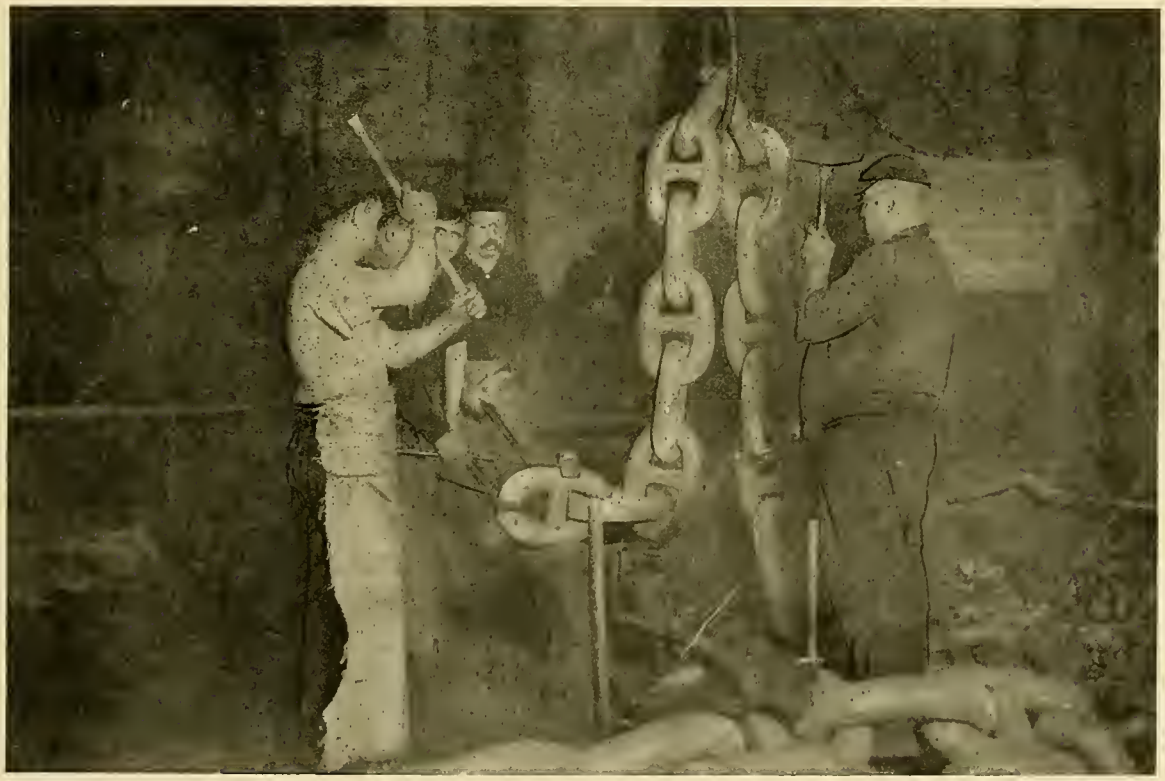

Fig. 17.—Seiting Stud.

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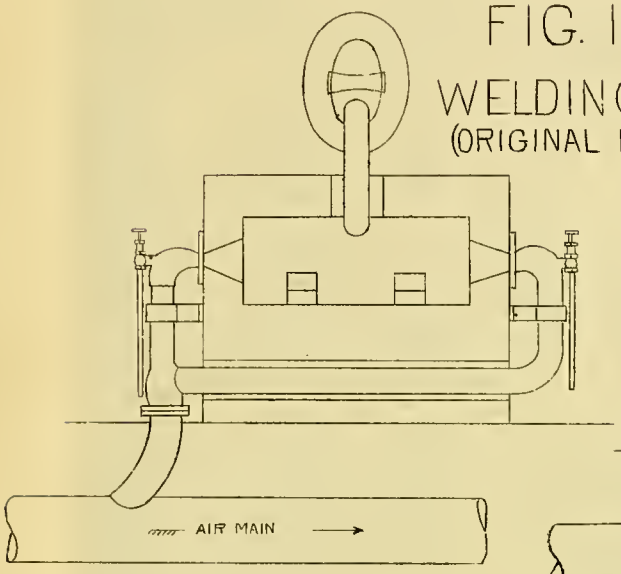

FIG. 18
WELDING FIRE
(ORIGINAL FORM)

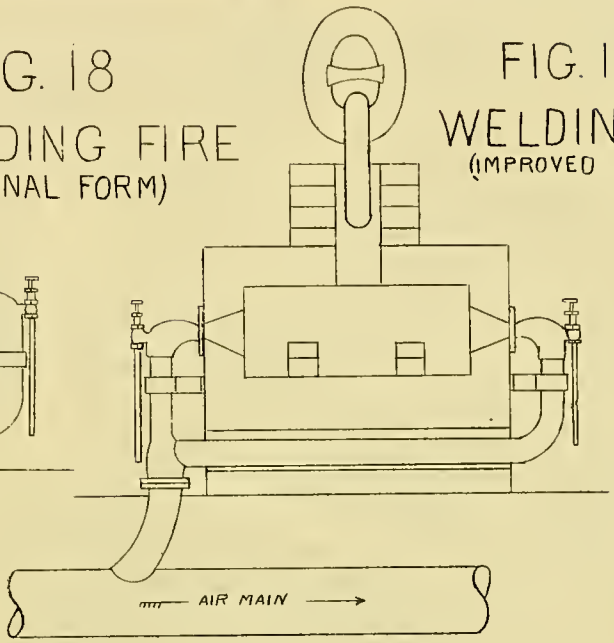

FIG. 18A
WELDING FIRE
(IMPROVED FORM)

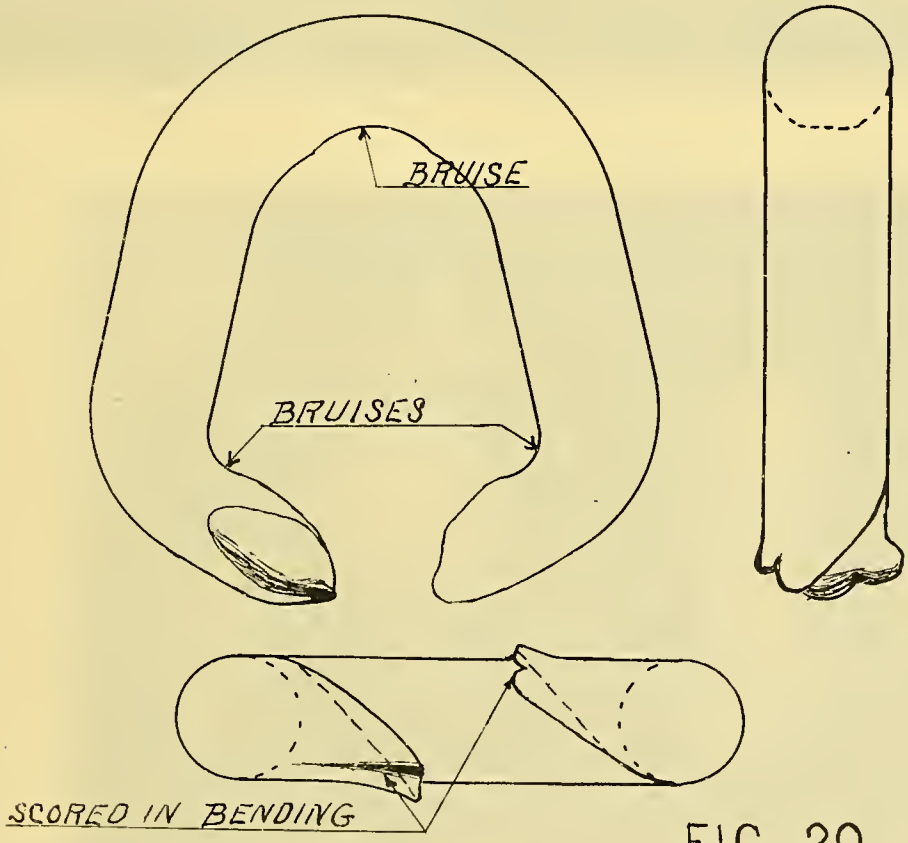

FIG. 20
CARTER LINK SHOWING DAMAGE

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To illustrate paper on "Notes on Chain Cables," by Assistant Naval Constructor John E. Otterson, U. S. N., Member.

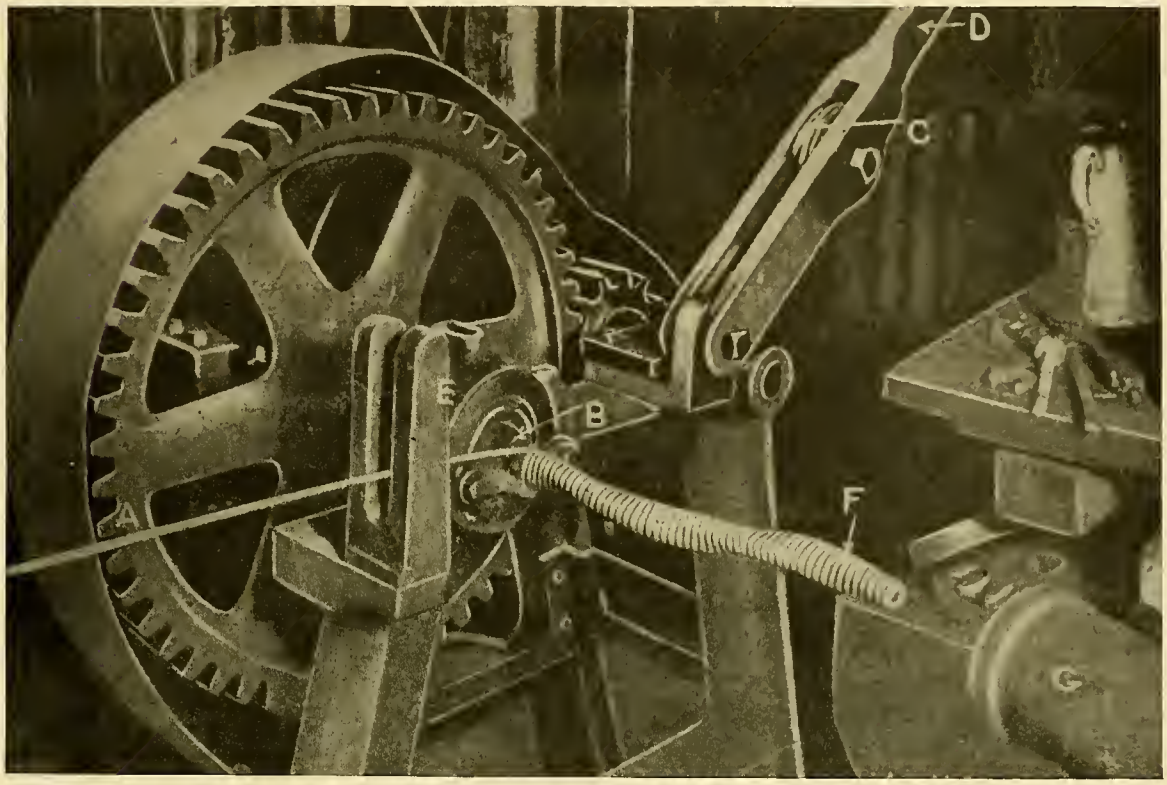

Fig. 19.—Winding Machine-made Links.

Fig. 19A.—Cutting the Link Blanks.

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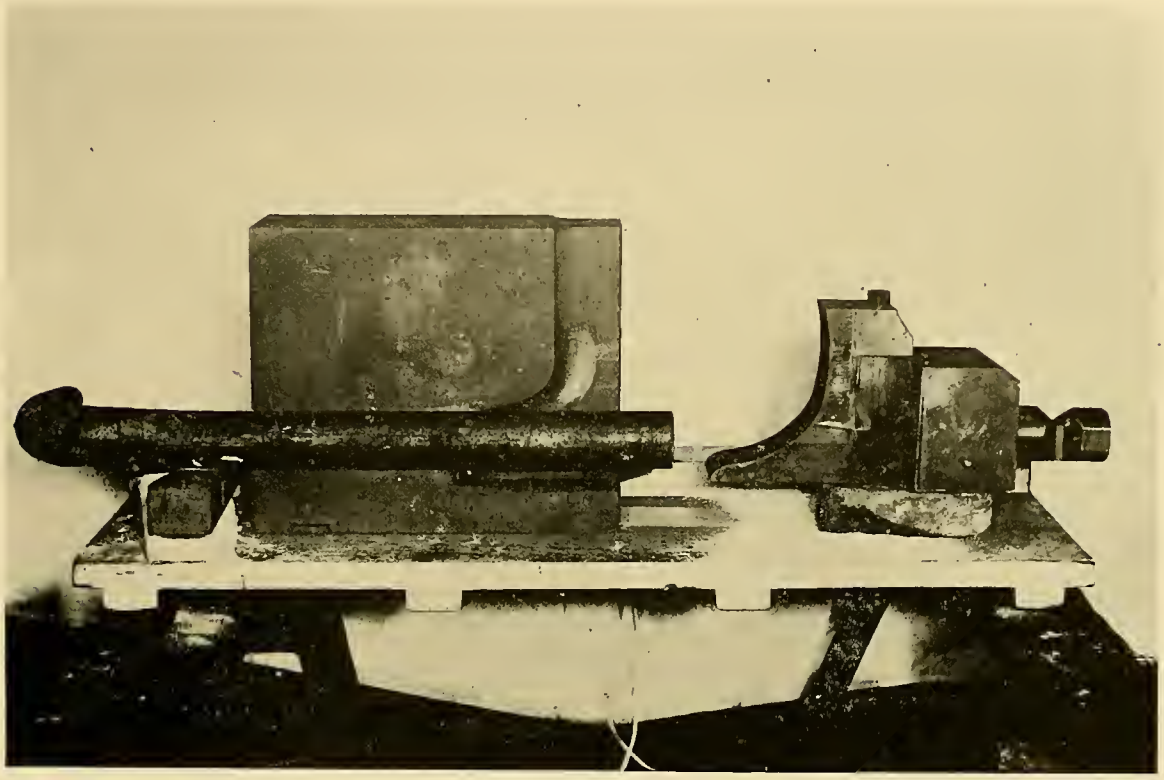

Fig. 21.

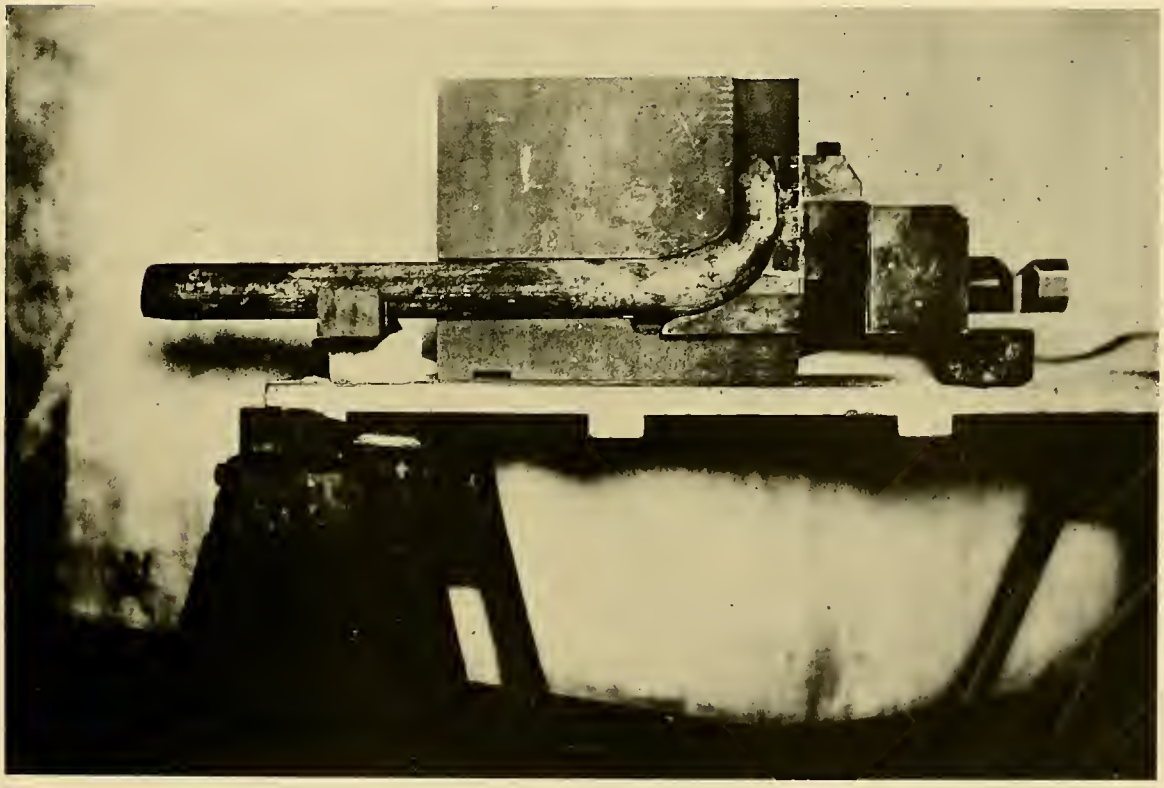

Fig. 21A.

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FIG-22

POOR SCARF

(EXAGGERATED)

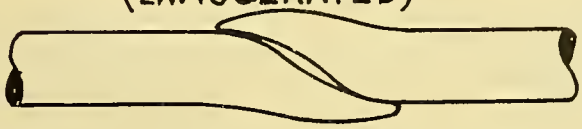
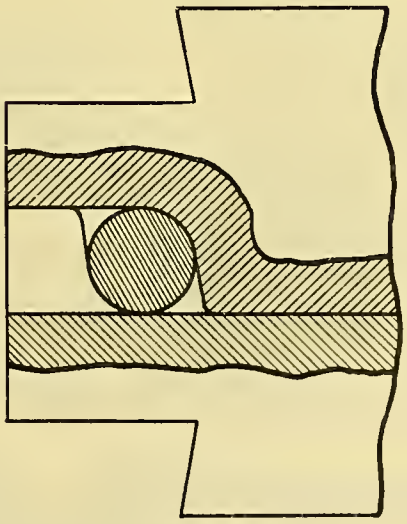


FIG-22-A

DESIRABLE SCARF

(EXAGGERATED)

FIG-27



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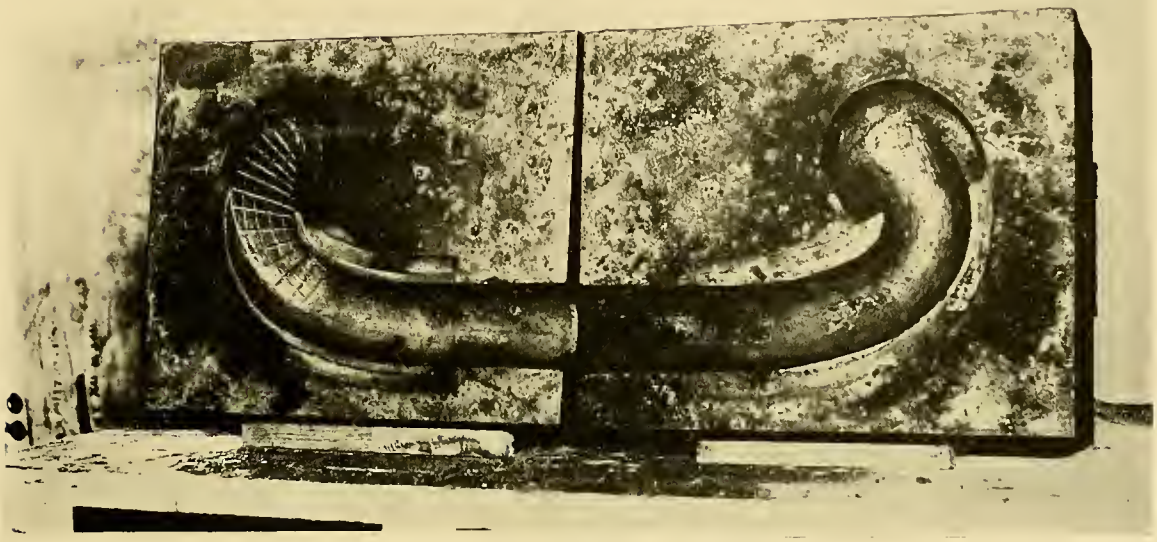

Fig. 23.

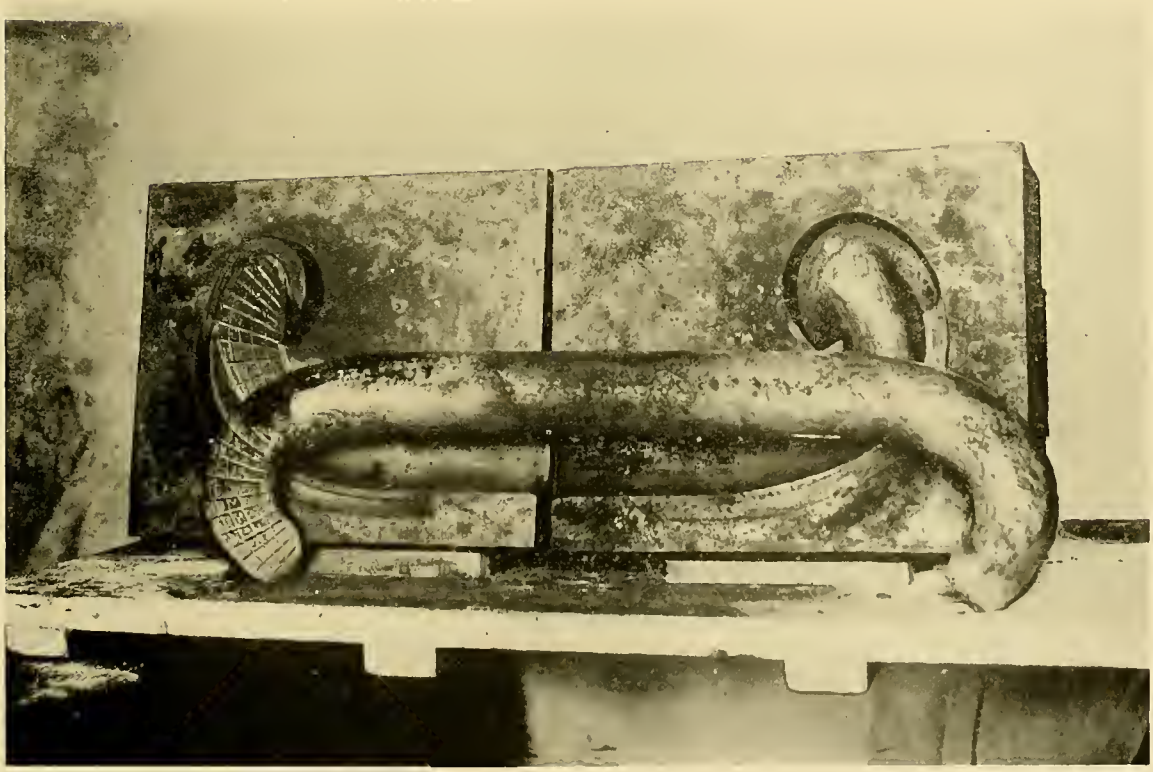

Fig. 23A.

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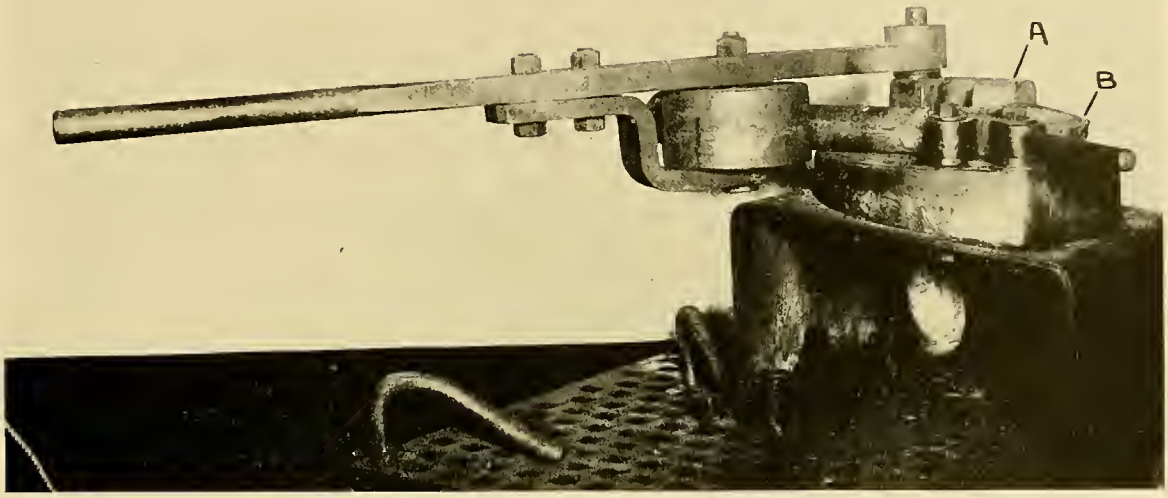

Fig. 24.

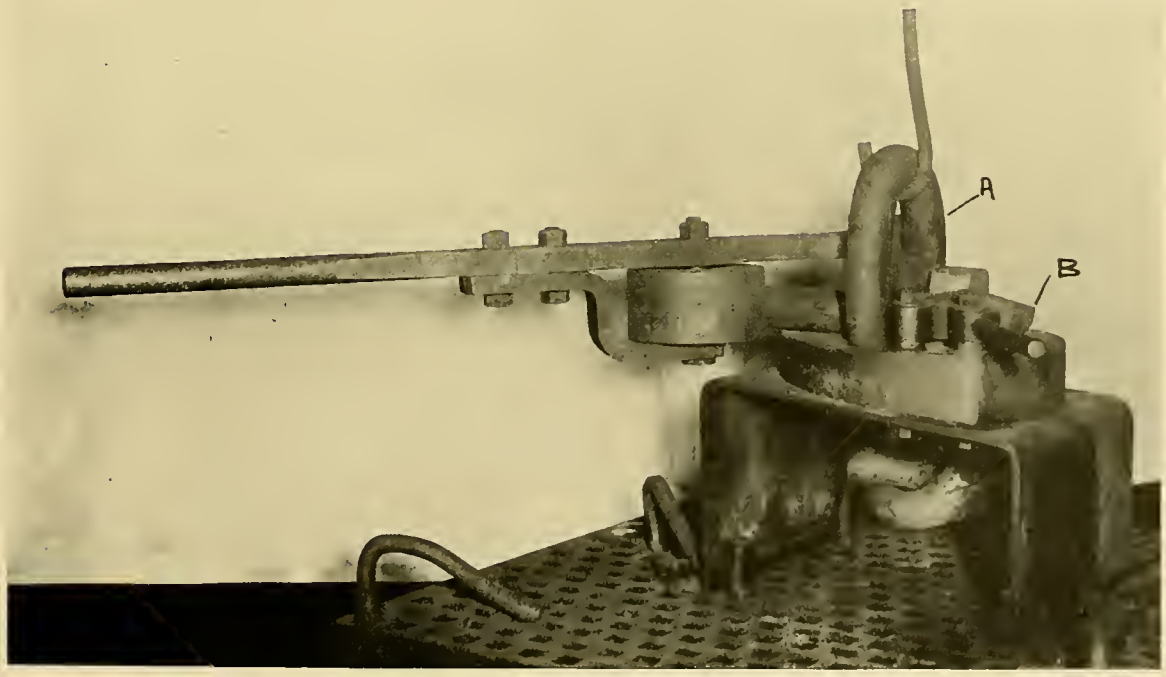

Fig. 25.

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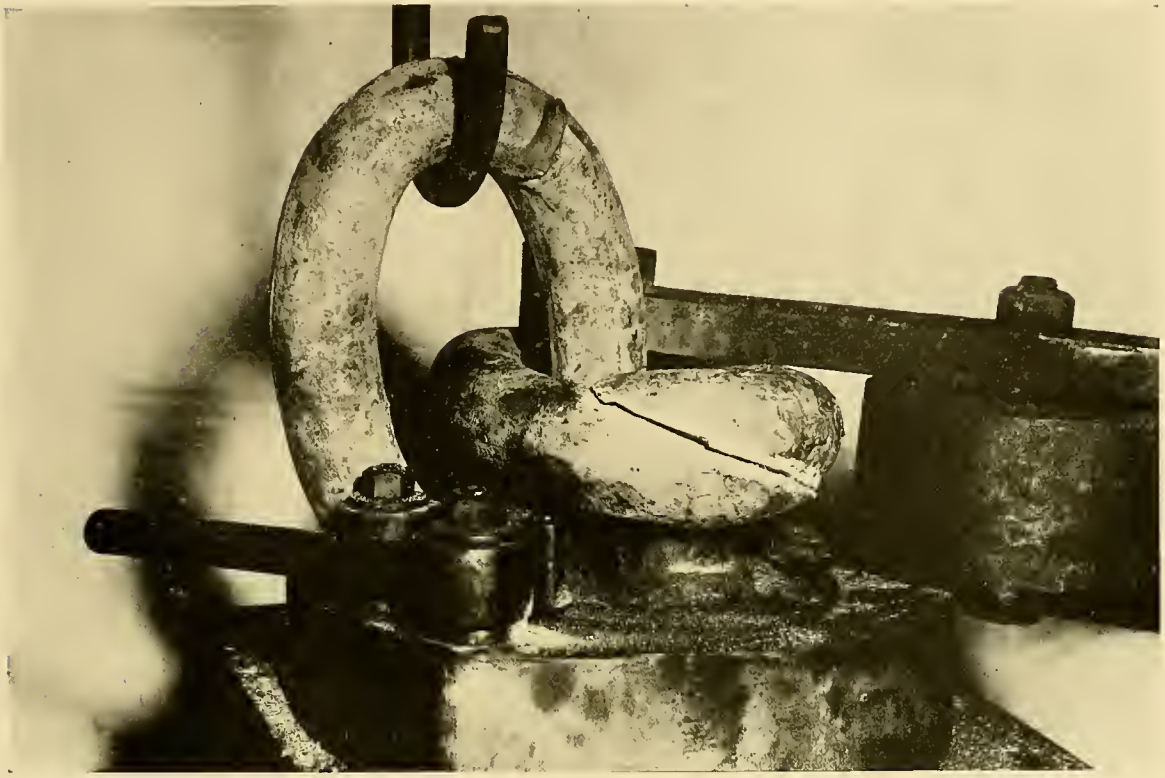

Fig. 26.

Fig. 28.—Making 5/16-inch Die-made Chain. Standish Hammer.

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by Assistant Naval Constructor John E. Otterson, U. S. N., Member.

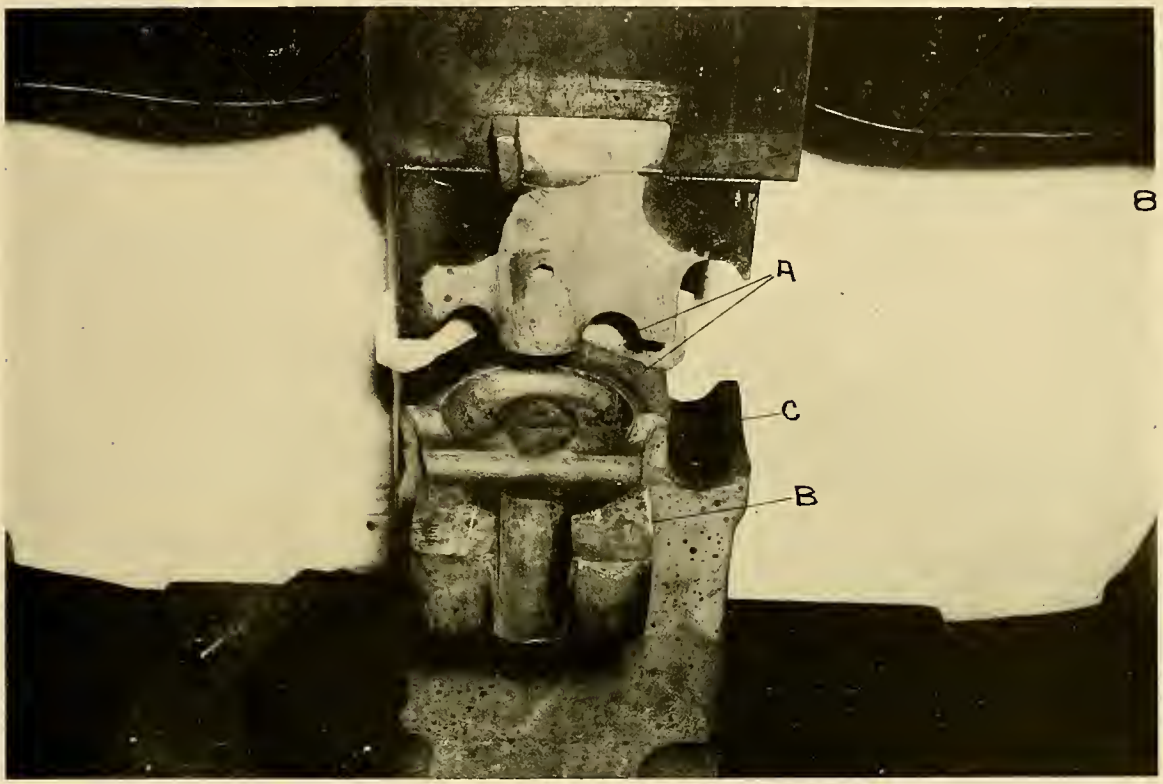

Fig. 29.

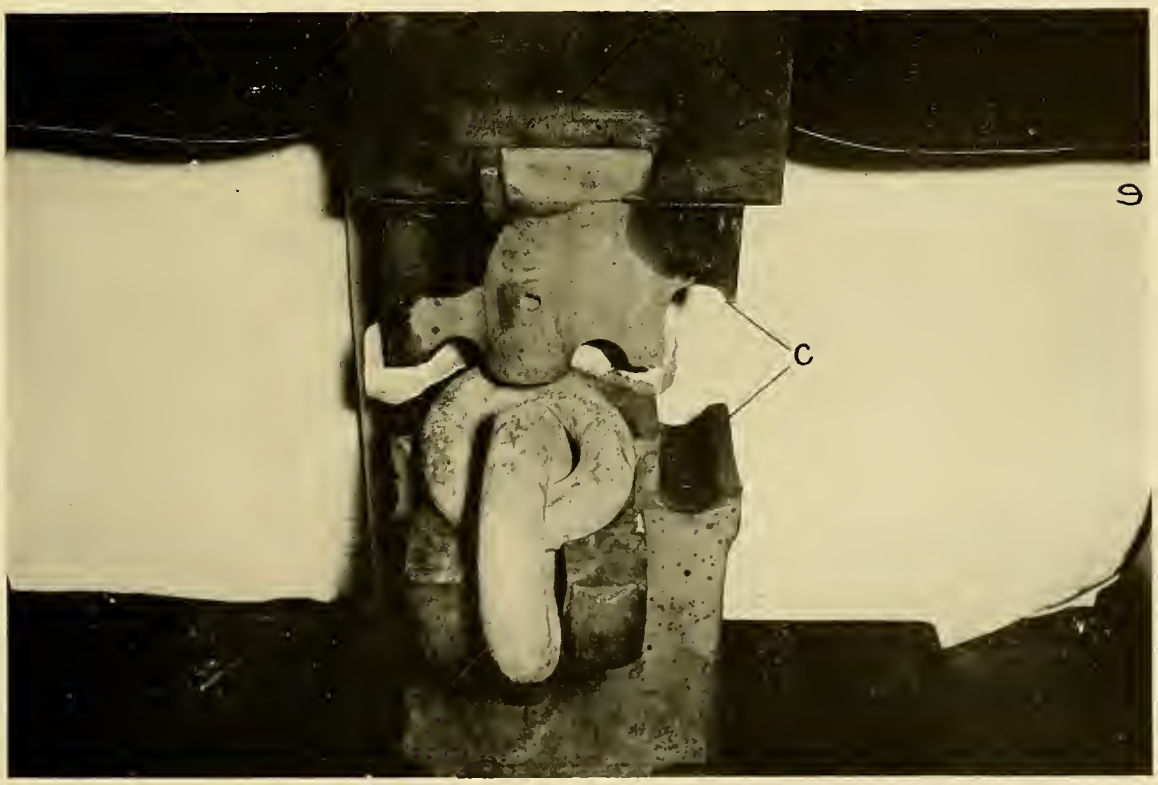

Fig. 30.

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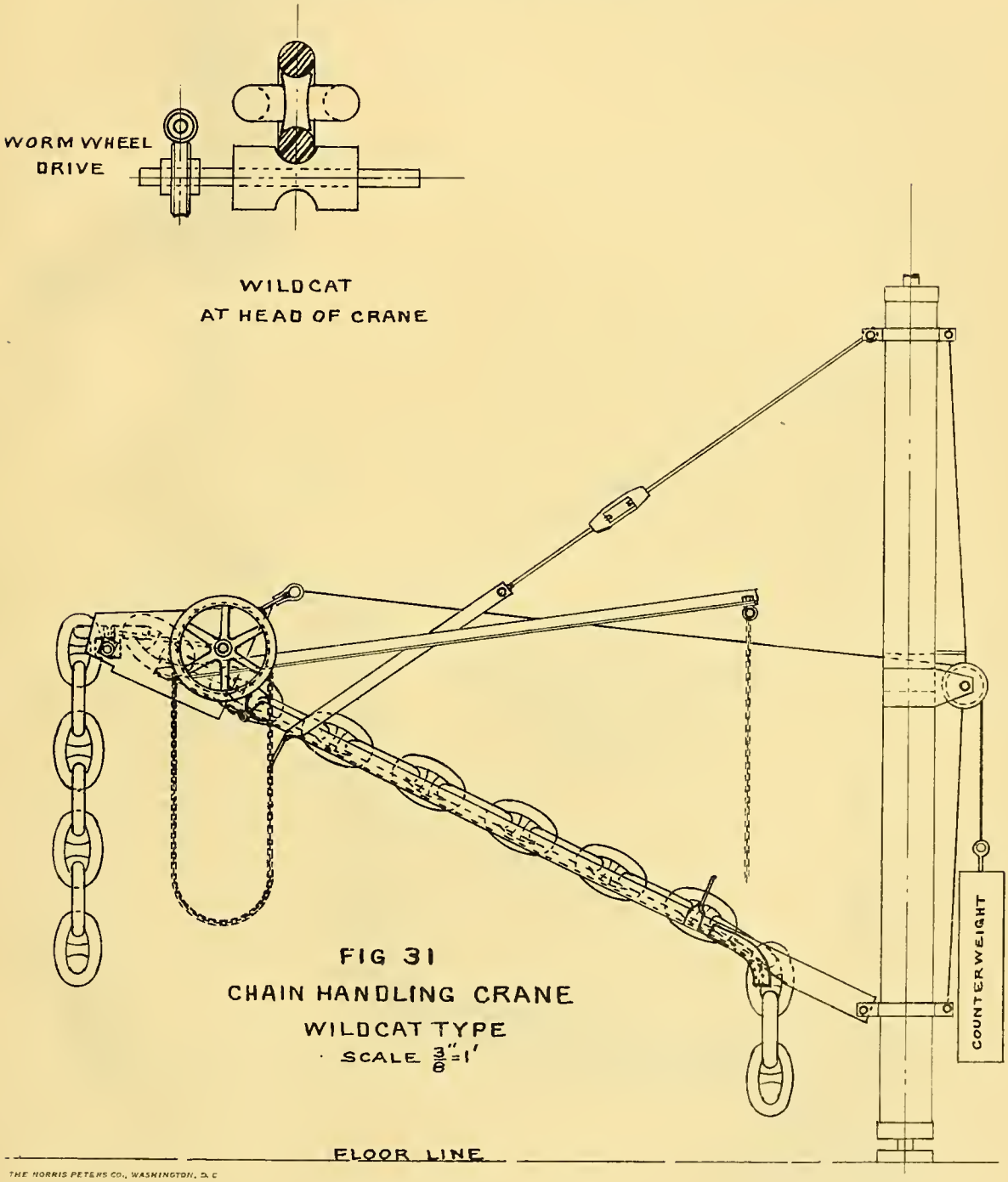

FIG 31
CHAIN HANDLING CRANE
WILDCAT TYPE
SCALE $\frac{3}{8}'' = 1'$

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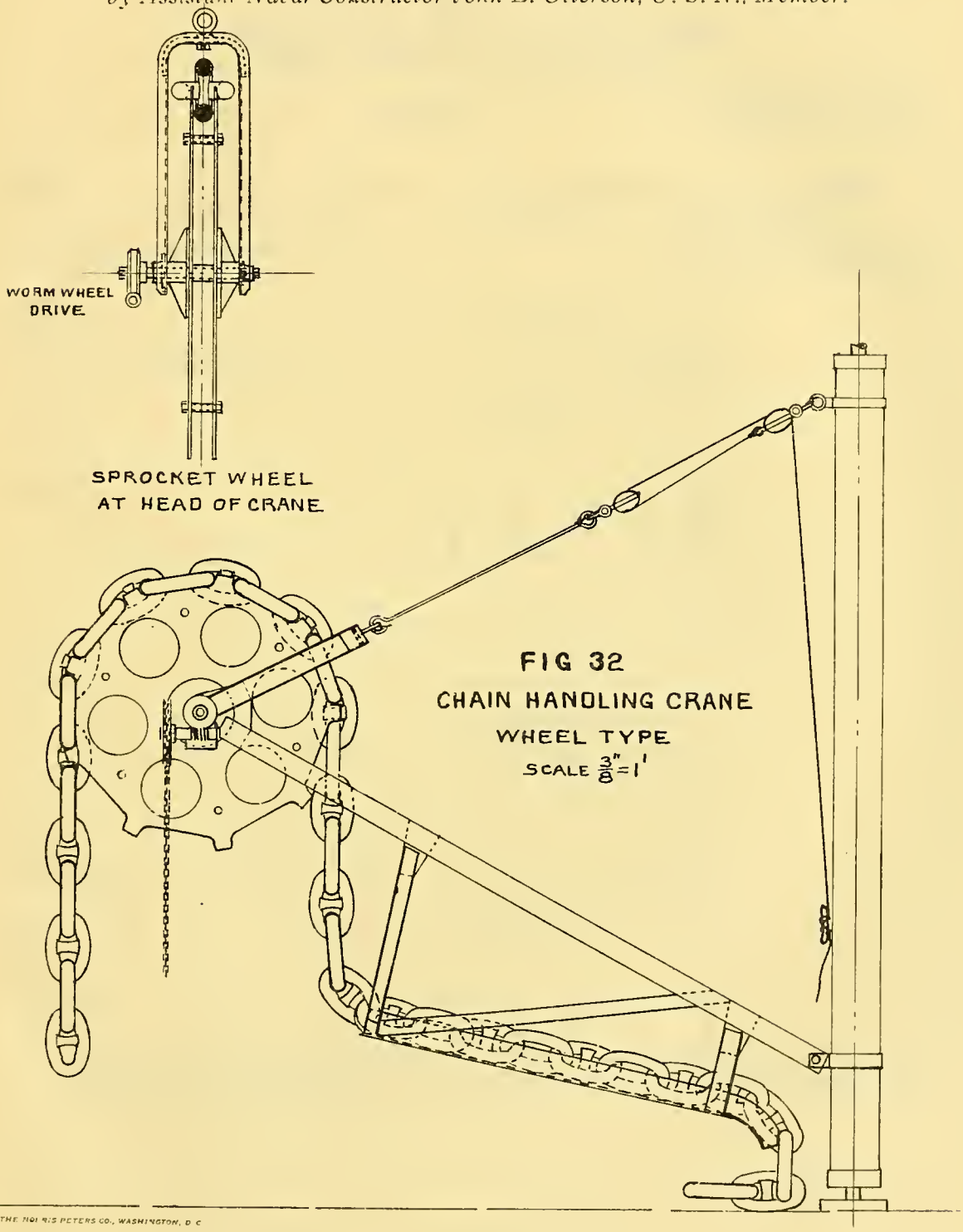

FIG 32
CHAIN HANDLING CRANE
WHEEL TYPE
SCALE $\frac{3''}{8}=1'$

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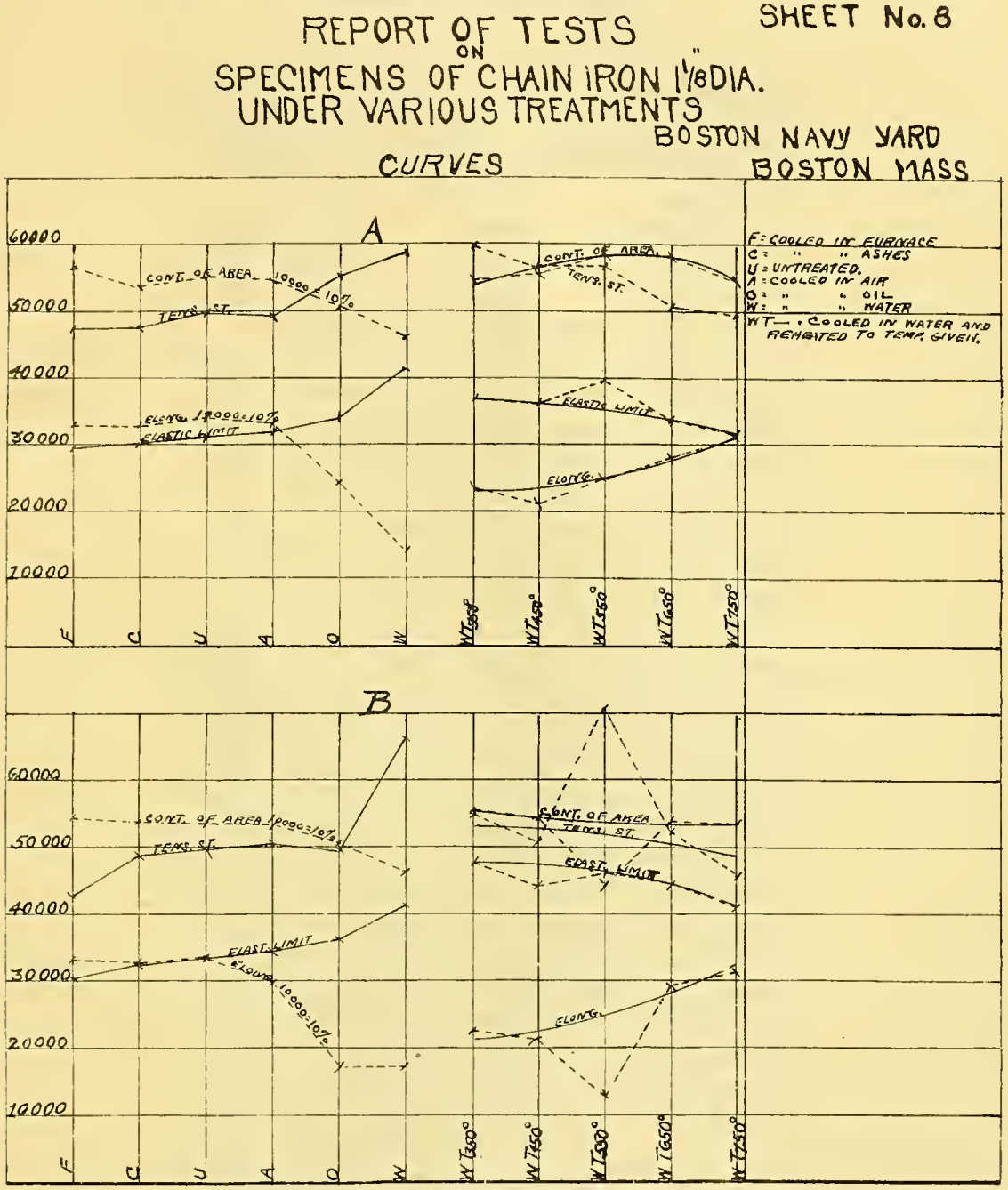

"B" SHOWS SAME TREATMENT ON IRON AS "A" EXCEPT IRON WAS RATTLED FOR 3 HOURS TO GET EFFECT OF VIBRATION.

FIG. 33

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TESTS OF CHAIN CABLE

COMPARISON OF ENGLISH AND UNITED STATES NAVIES

DIAMETER OF IRON COMMON LINKS	STATUTORY PROOF STRESS ENGLISH	STATUTORY PROOF STRESS U.S. NAVY	STATUTORY BREAKING STRESS ENGLISH	STATUTORY BREAKING STRESS U.S. NAVY	ACTUAL BREAKING STRESS	
					GOOD ORDINARY CABLE	HIGH BREAKING STRESS
INCHES	POUNDS	POUNDS	POUNDS	POUNDS	POUNDS	POUNDS
$\frac{3}{4}$	22680		34026		36288	38752
$\frac{13}{16}$	26600		39900		42560	45640
$\frac{7}{8}$	30800		46200		49560	52920
$\frac{15}{16}$	35392		53088		56896	61040
1	40320	34607	60480	67526	64960	69664
$1\frac{1}{16}$	45472	39200	68208	75000	73080	78176
$1\frac{1}{8}$	50960	43812	76440	82686	81760	87360
$1\frac{3}{16}$	56840	49200	85260	91200	90720	97160
$1\frac{1}{4}$	63000	54194	94506	100630	100240	107296
$1\frac{5}{16}$	69440	59748	104160	109771	110040	117880
$1\frac{3}{8}$	76160	65574	114240	119355	120400	128800
$1\frac{7}{16}$	83160	71672	124740	129385	131320	140448
$1\frac{1}{2}$	90720	78041	136080	139861	142464	152320
$1\frac{9}{16}$	98336	84678	147504	150783	153888	164864
$1\frac{5}{8}$	106400	91588	159600	162152	165760	177632
$1\frac{11}{16}$	114800	98600	172200	174000	178360	190848
$1\frac{3}{4}$	123480	106222	185226	186228	191240	204680
$1\frac{13}{16}$	132440	113900	190660	198800	204288	218680
$1\frac{7}{8}$	141680	121937	212531	212088	217840	233240
$1\frac{15}{16}$	151200	130202	226800	225687	231840	248192
2	161280	138739	241920	239732	246176	263480
$2\frac{1}{16}$	171360	147544	257040	254223	260736	279160
$2\frac{1}{8}$	182000	156622	273011	269160	275800	295456
$2\frac{3}{16}$	192920	166000	289380	284000	291424	311920
$2\frac{1}{4}$	204120	175591	306180	300373	307160	328720
$2\frac{5}{16}$	215600	185200	323400	316200	323120	346080
$2\frac{3}{8}$	227360	195200	340928	333200	339640	363776
$2\frac{7}{16}$	239456	205800	359184	350100	356608	381696
$2\frac{1}{2}$	252000	216779	378112	368153	373800	400120
$2\frac{9}{16}$	264768	227800	397152	385900		
$2\frac{5}{8}$	277830	238995	416745	404719		
$2\frac{11}{16}$		250500		423200		
$2\frac{3}{4}$	289632	262302	434560	443069		
$2\frac{13}{16}$		275000		462600		
$2\frac{7}{8}$	299943	286692	449914	483203		
$2\frac{15}{16}$		299300		503900		
3	326592	312165	489888	525121		

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FIG. 34.

To illustrate paper on "Notes on Chain Cables," by Assistant Naval Constructor John E. Otterson, U. S. N., Member.

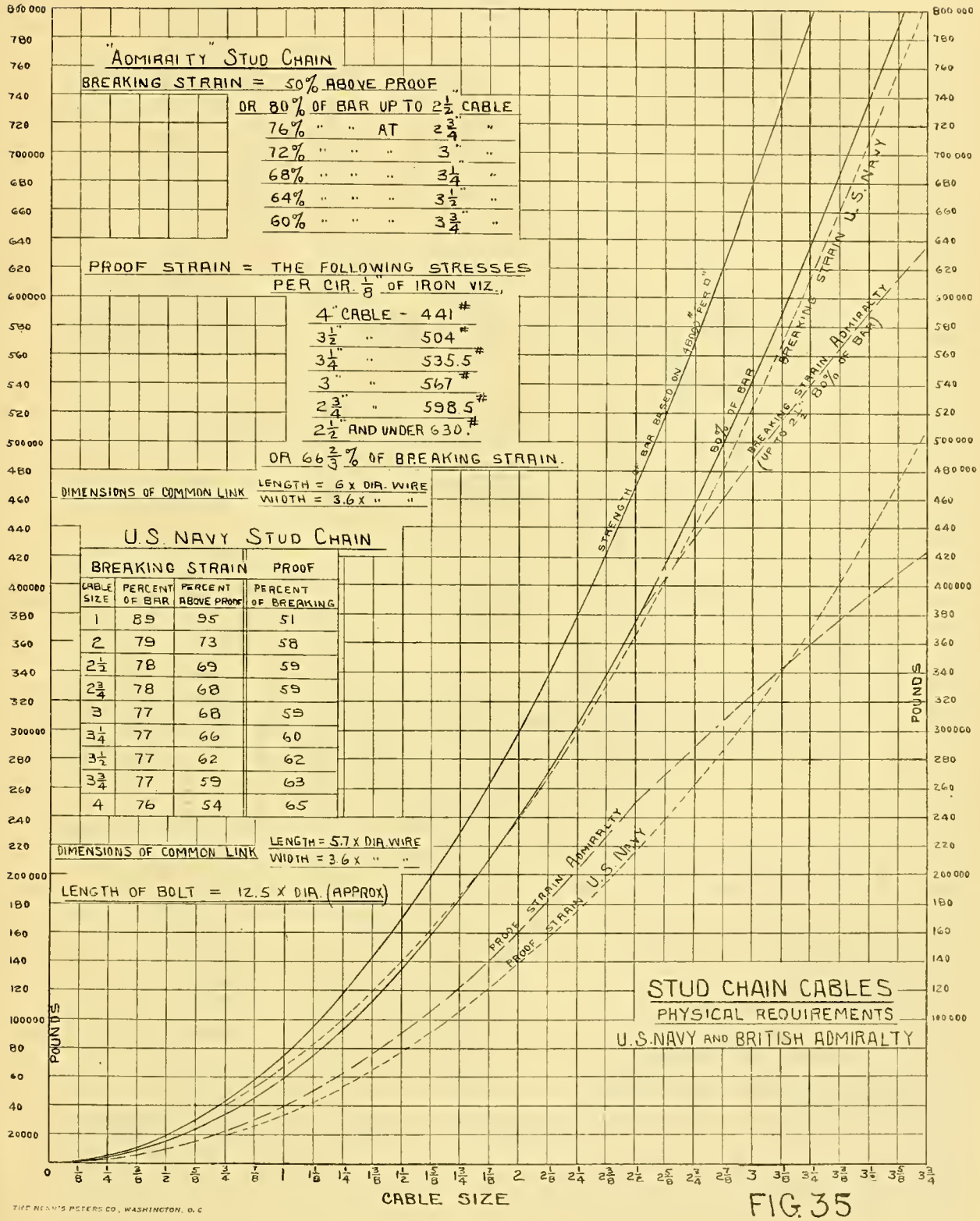

FIG. 35

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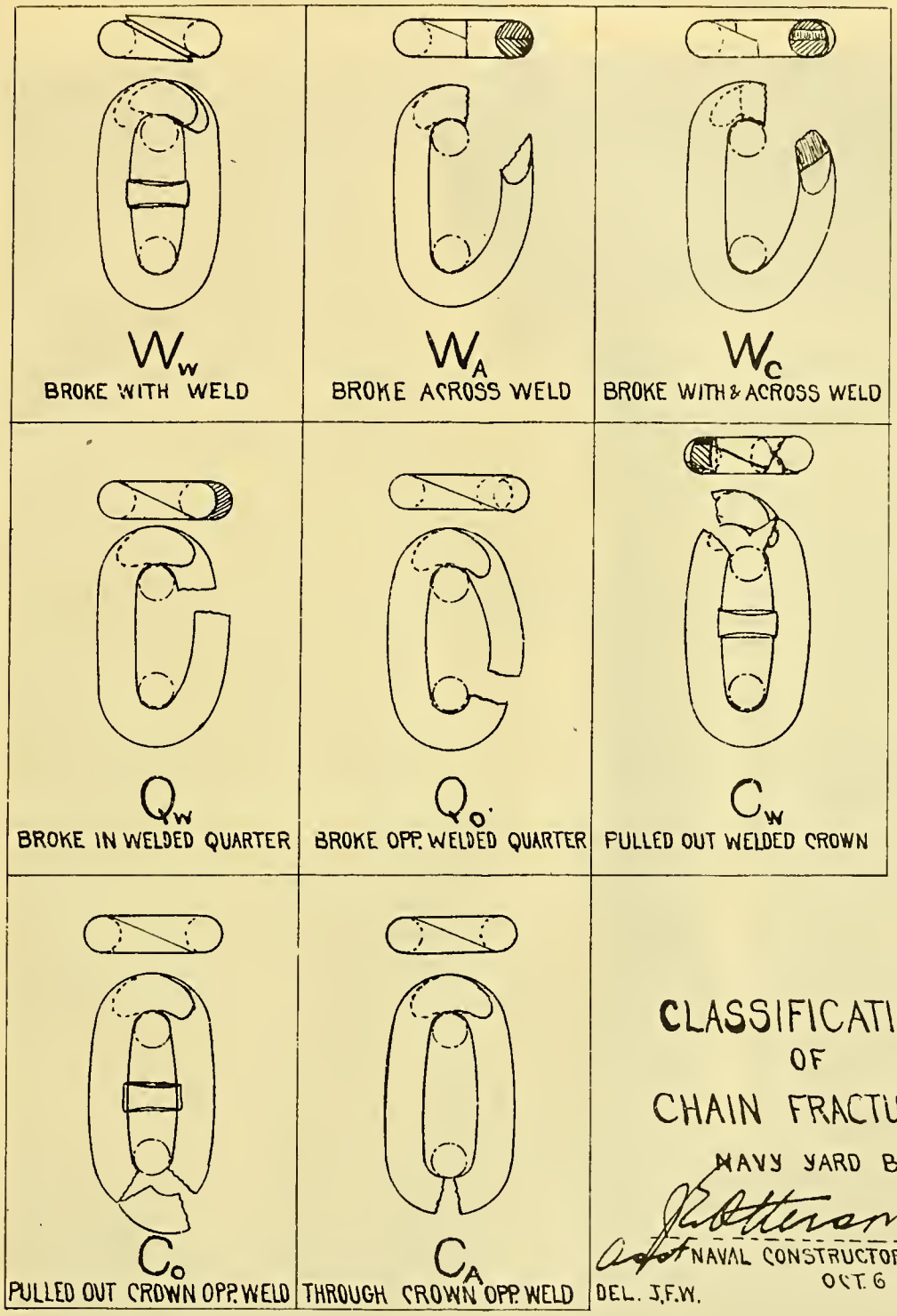
by Assistant Naval Constructor John E. Otterson, U. S. N., Member.



CLASSIFICATION
OF
CHAIN FRACTURES

NAVY YARD BOSTON

J. E. Otterson
Asst NAVAL CONSTRUCTOR U.S.N.
OCT. 6 1913

DEL. J.F.W.

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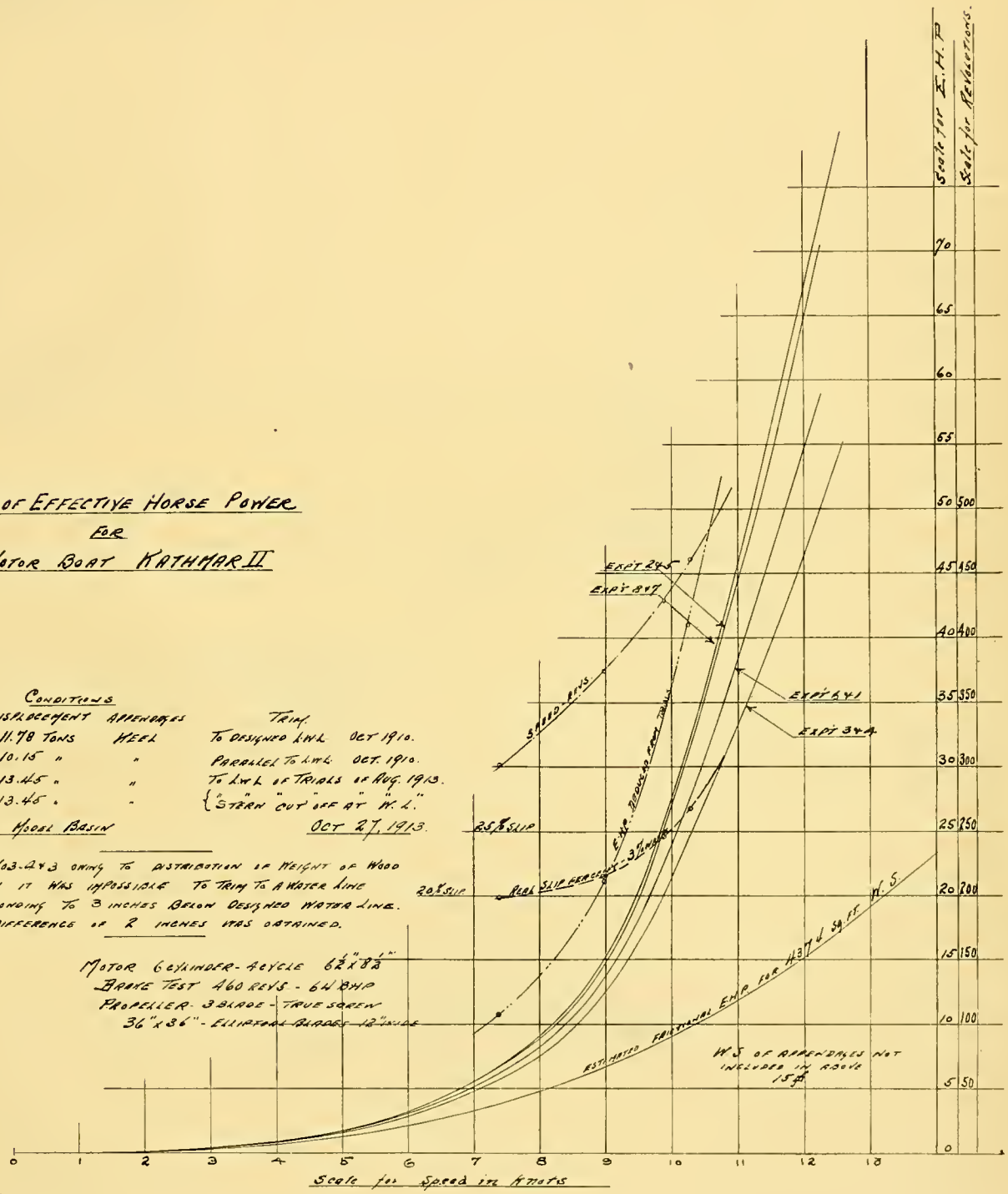
FIG. 36

To illustrate paper on "Model Experiments and Speed Trials of 60-Foot Motor Cruiser Kathmar II," by A. E. Luders, Esq., Member.

To illustrate paper on "Model Experiments and Speed Trials of 60-Foot Motor Cruiser Kathmar II," by A. E. Luders, Esq., Member.



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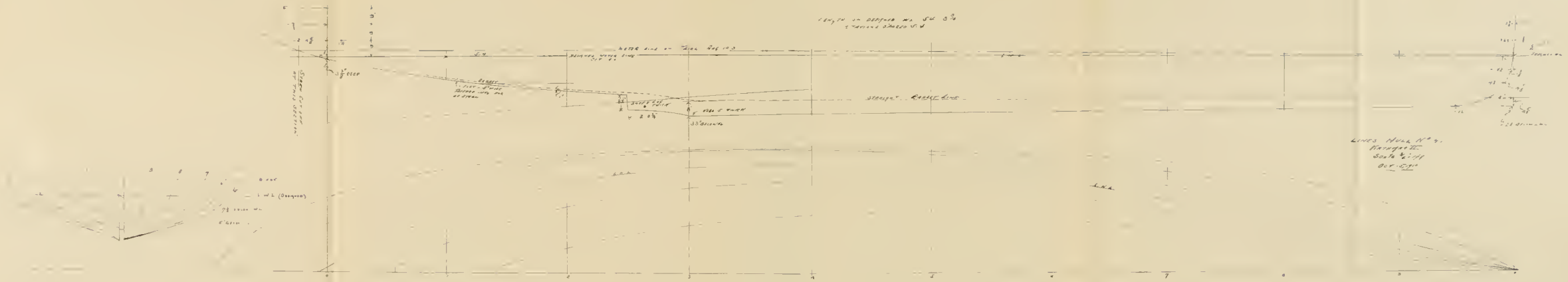
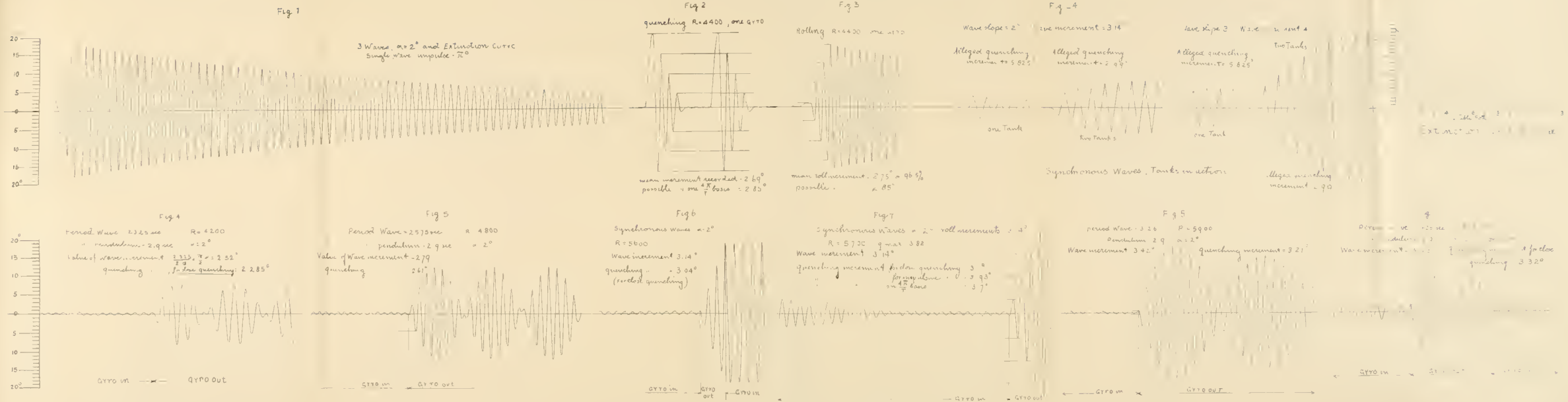
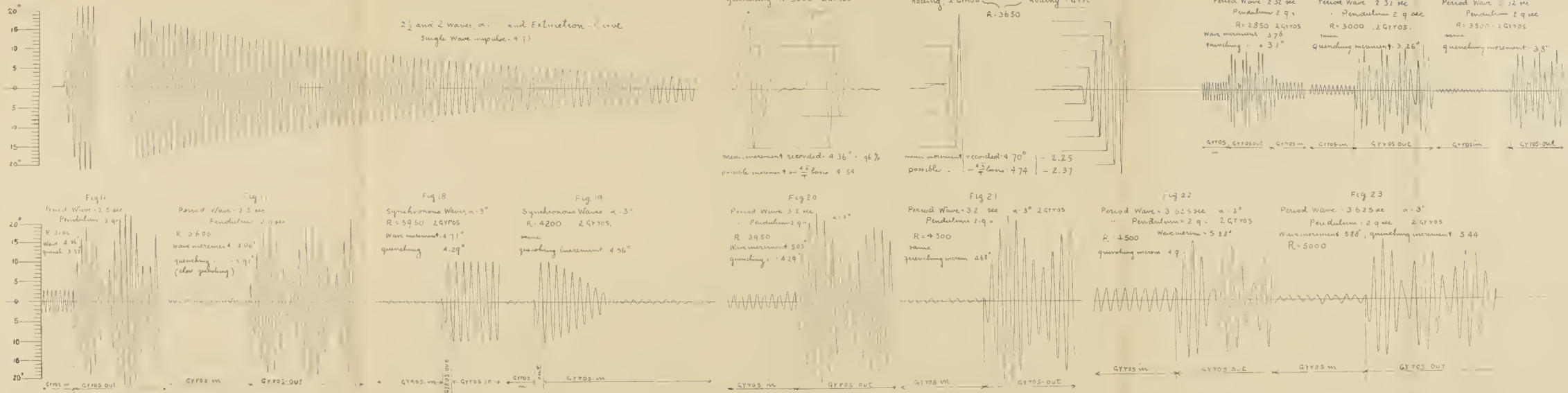
To illustrate paper on "Model Experiments and Speed Trials of 60-Foot Motor Cruiser Kothmar II." by A. E. Luders, Esq., Member.



To illustrate paper on Some Graphic Studies of the Active Gyro Stabilizer
by Elmer A. Sperry, Esq., Member



To illustrate paper on "Some Graphic Studies of the Active Gyro Stabilizer,"
by Elmer A. Sperry, Esq., Member



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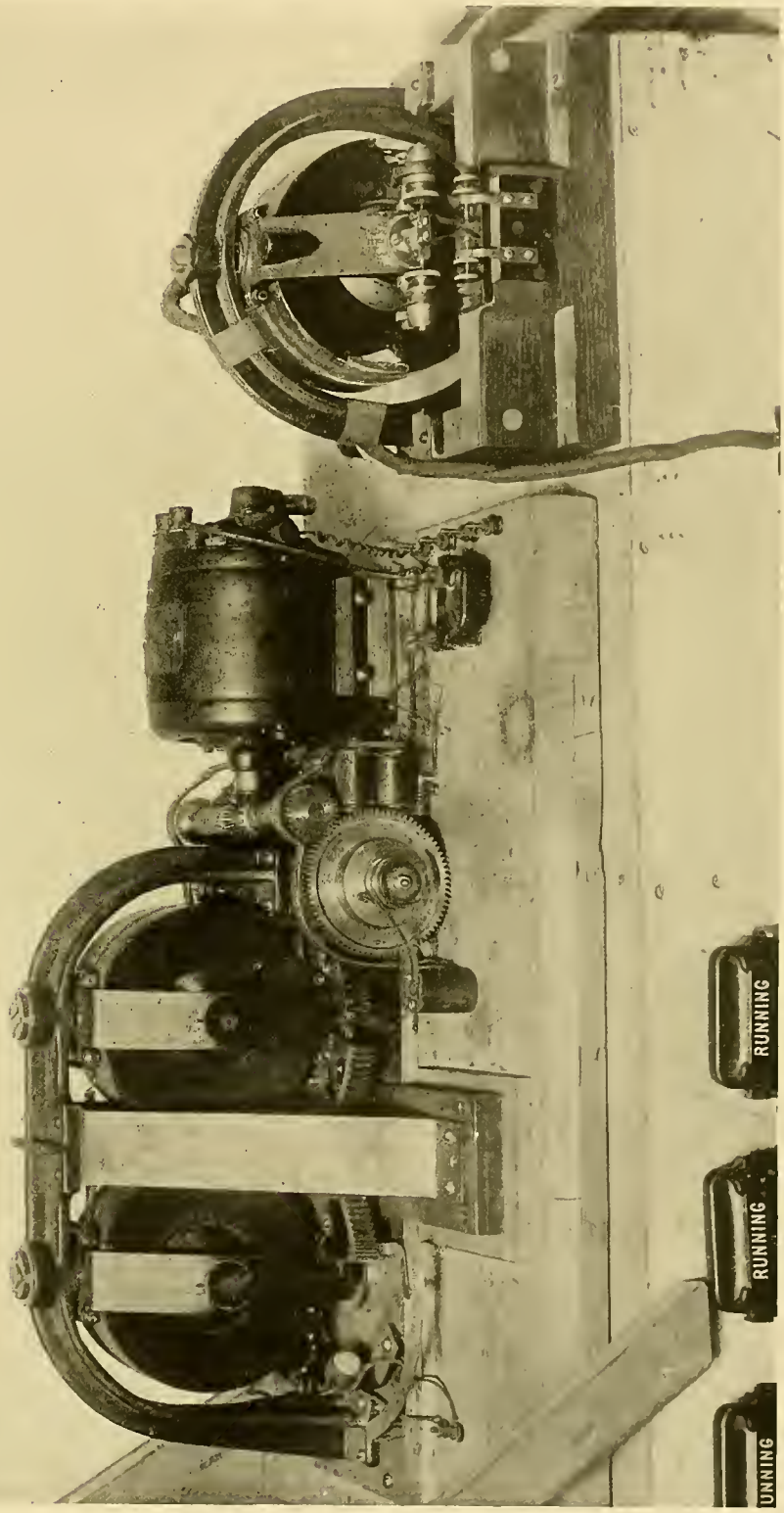

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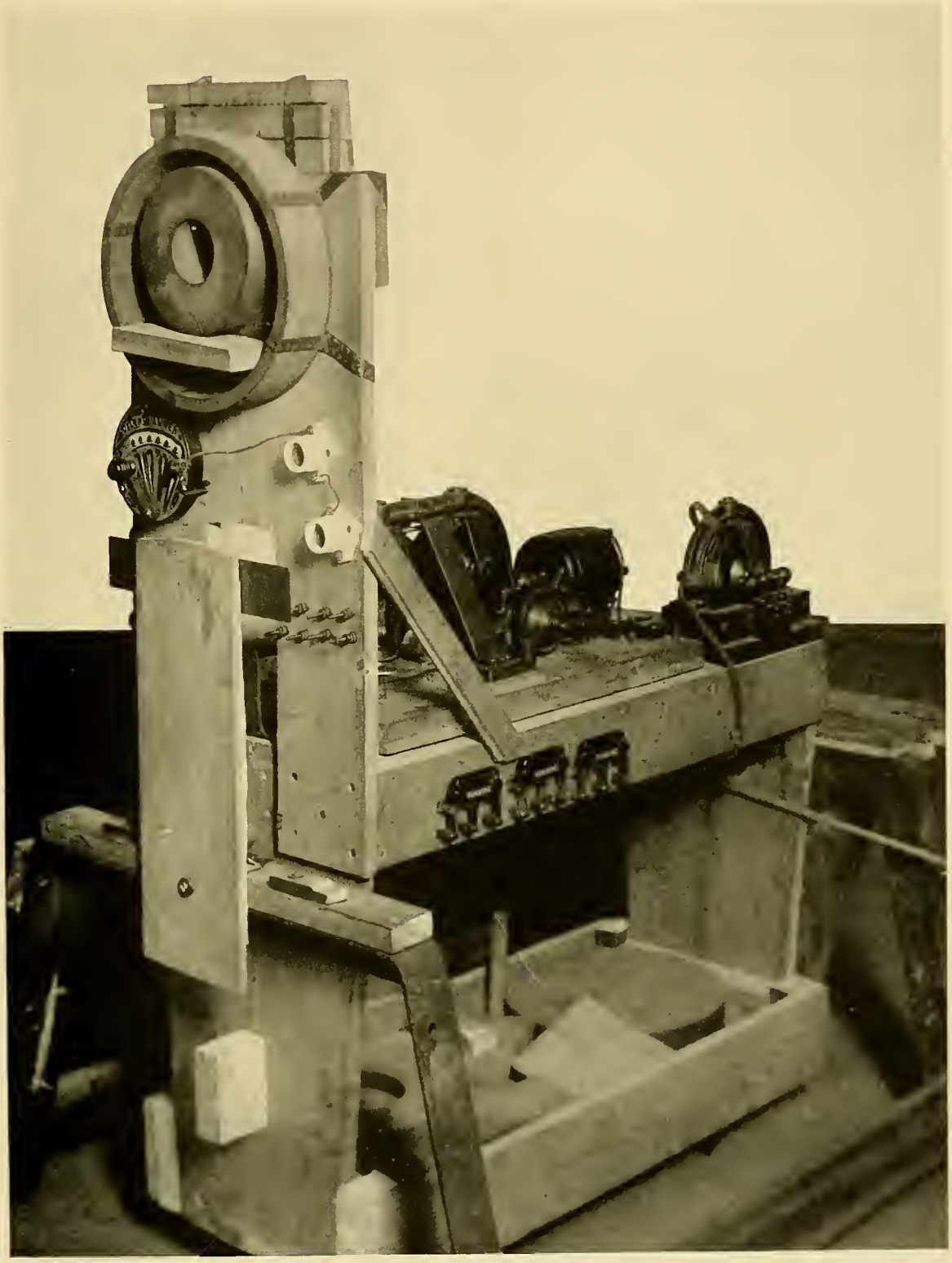

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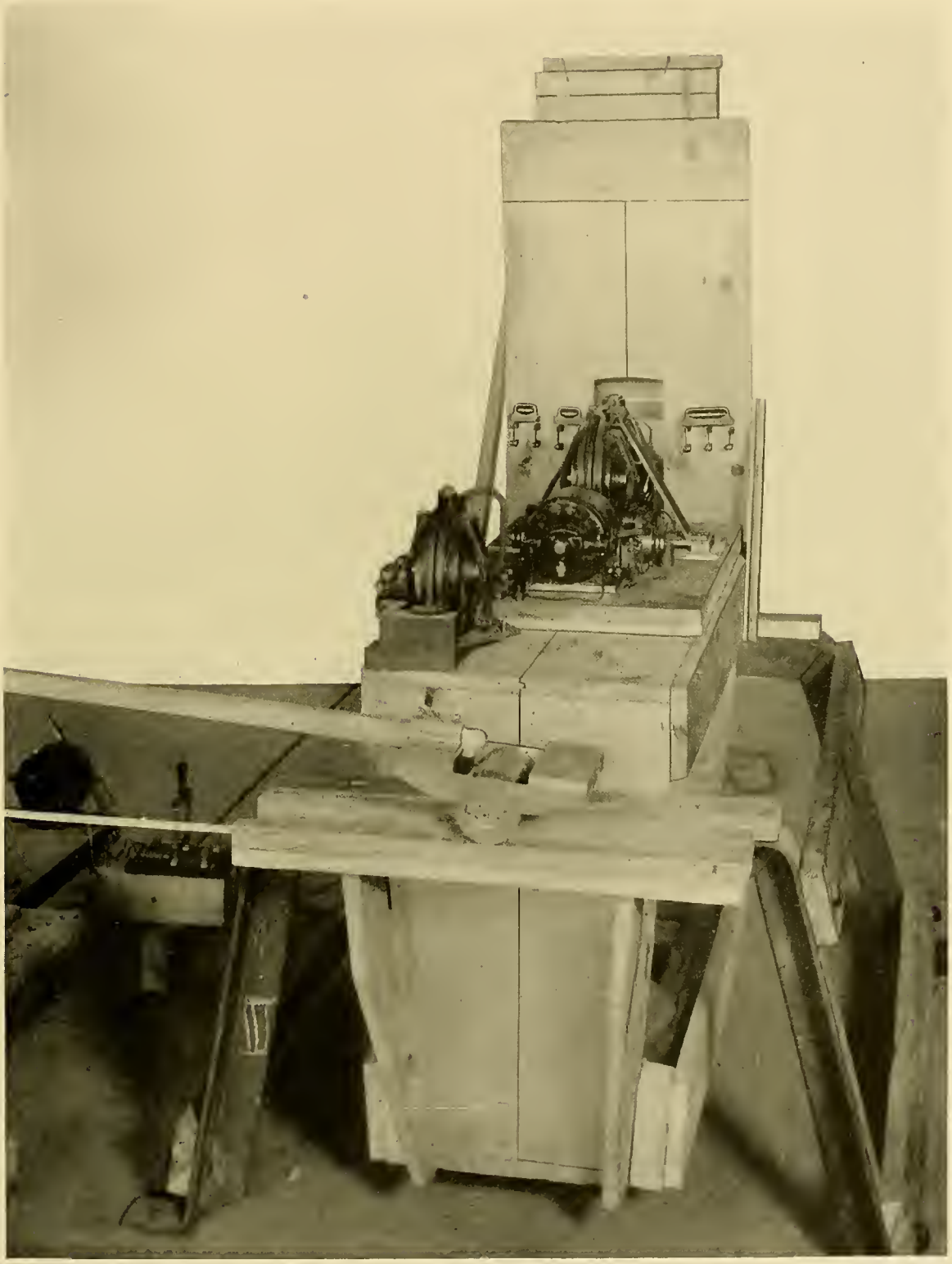

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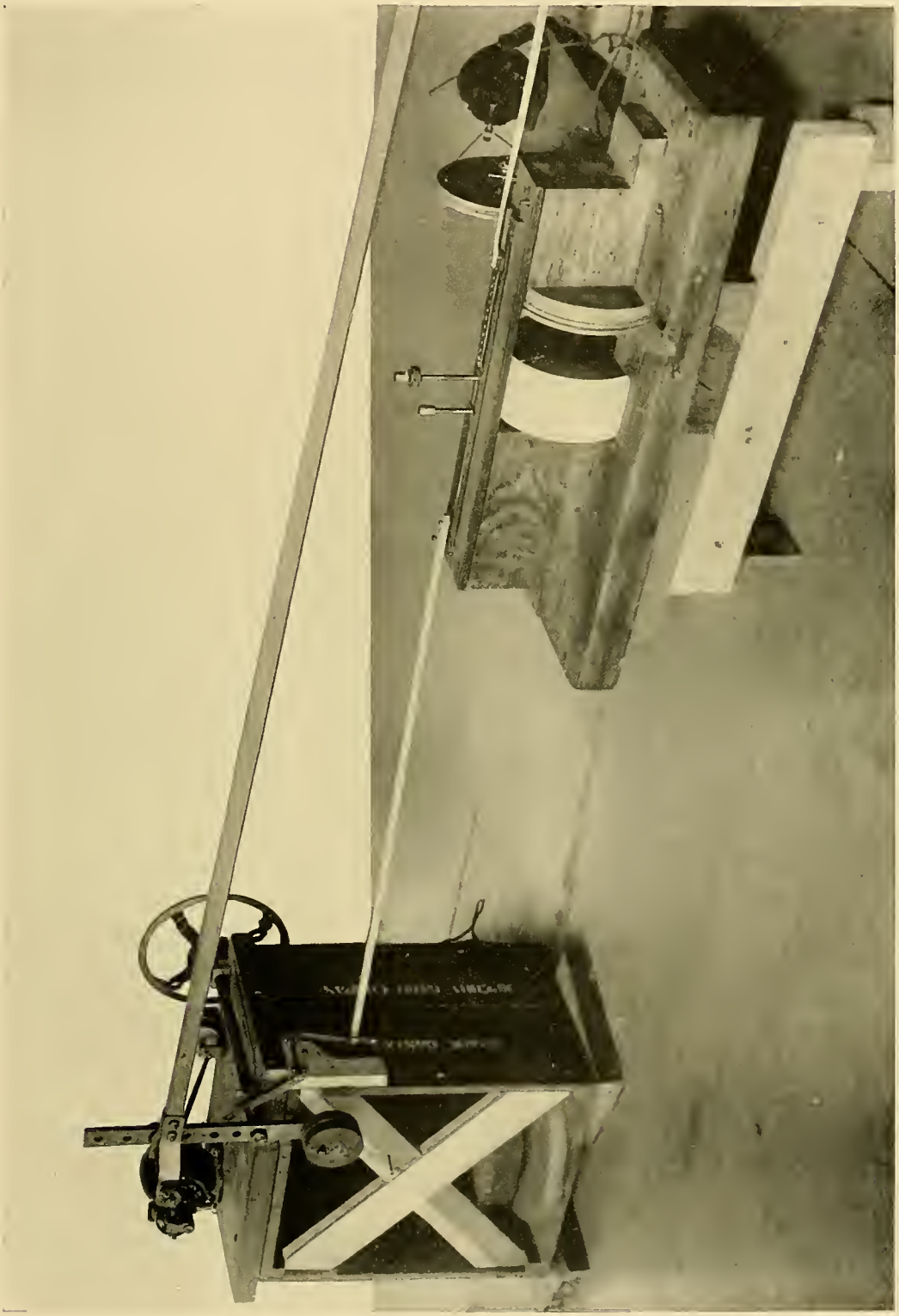
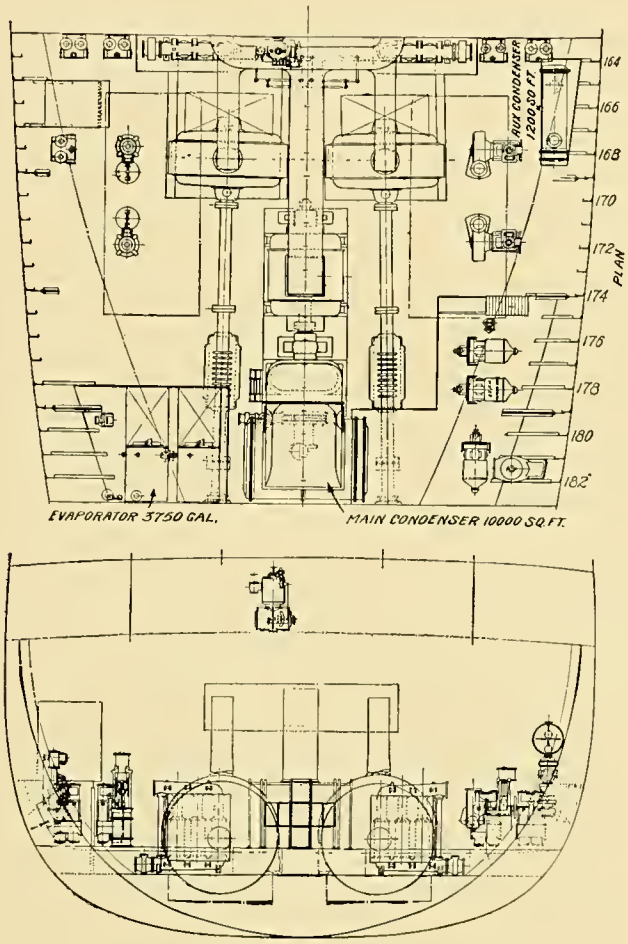
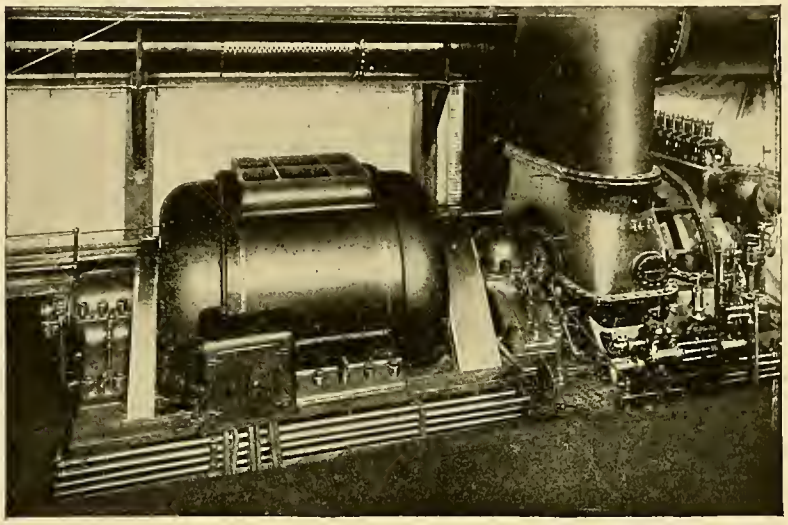


To illustrate paper on "Electric Propulsion on the U. S. S. Jupiter," by W. L. R. Emmet, Esq., Member.

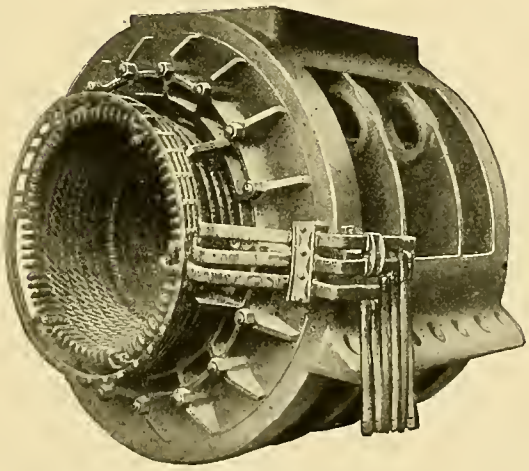


ARRANGEMENT OF MACHINERY.

To illustrate paper on "Electric Propulsion on the U. S. S. Jupiter," by W. L. R. Emmet, Esq., Member.

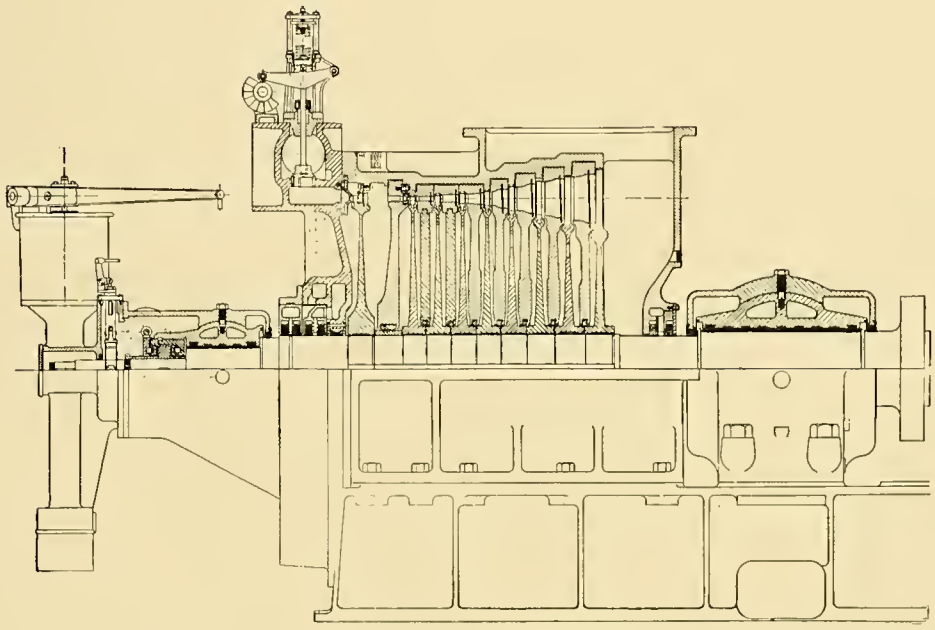


Generating Unit.

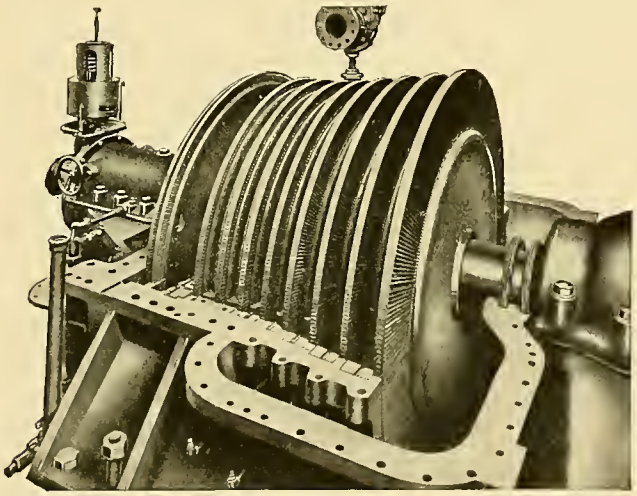


Stator Frame and Windings of Generator.

To illustrate paper on "Electric Propulsion on the U. S. S. Jupiter," by W. L. R. Emmet, Esq., Member.

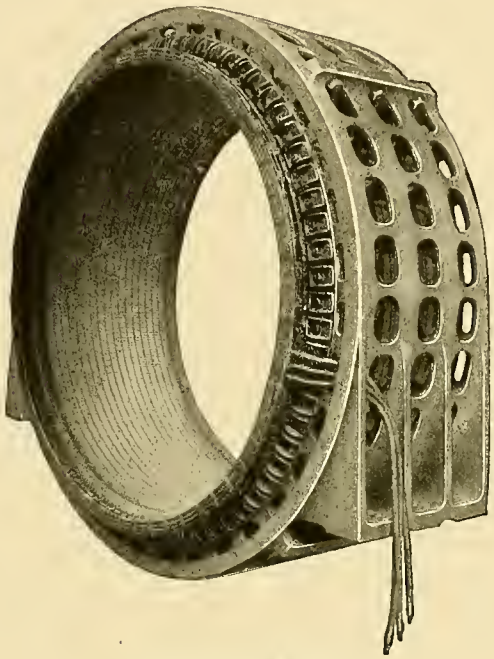


Cross-Section of Turbine.

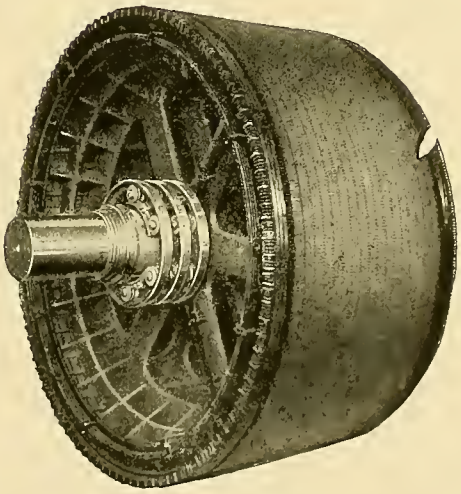


Turbine for U. S. Collier Jupiter Mid-Bearing Cap and Top Intermediate Holder. Intermediates and Nozzles Removed.

To illustrate paper on "Electric Propulsion on the U. S. S. Jupiter," by W. L. R. Emmet, Esq., Member.



STATOR FOR MOTOR.



ROTOR FOR MOTOR.

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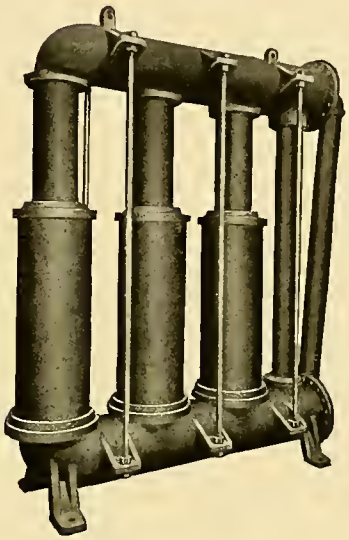
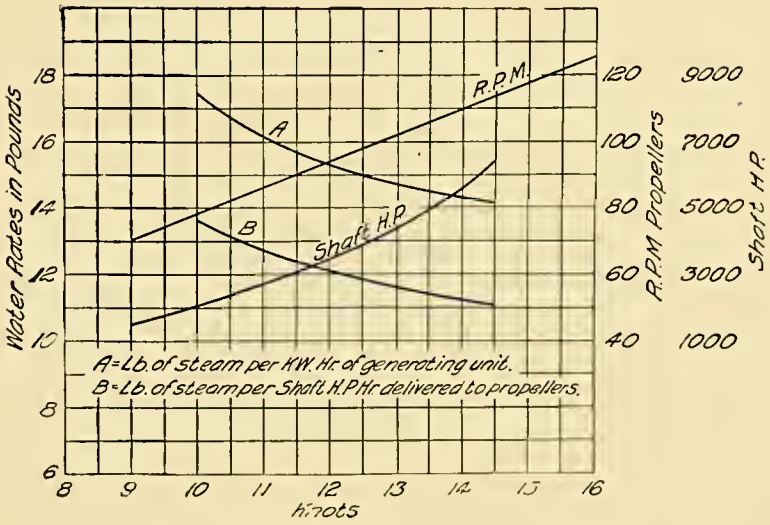


WATER-COOLED RHEOSTAT.



WATER RATES U. S. S. JUPITER—CONDITIONS 190-LB. GAUGE, 28.5-IN. VACUUM, NO SUPERHEAT.

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